Normal Pension Age for Firefighters

A review for the Firefighters' Pension Committee

December 2012

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12 January 2013

Authors:

Dr Anthony N. Williams LLM FFOM
Chair, Consultant Occupational Physician, Working Fit Ltd
Dr David M. Wilkinson PhD
Occupational Physiologist, Optimal Performance Ltd
Dr Victoria L. Richmond PhD
Occupational Physiologist, Optimal Performance Ltd
Dr Mark P Rayson PhD
Occupational Physiologist, Optimal Performance Ltd

Additional evidence and contributions have been made by others including those listed below, but this paper does not represent their opinions and they have not endorsed the findings or the recommendations:

Richard Stevenson MSc PGDip ACSM-HFS
Senior Health & Fitness Adviser, South Wales Fire & Rescue Service
James Dalgliesh
London Fire Brigade, on behalf of the Local Government Association
Sean Starbuck, Ian Murray
Fire Brigades Union, on behalf of the employees

Document reviewers:

Dr John Hobson FFOM
Consultant Occupational Physician, Hobson Health Ltd
Dr Doug Andrews PhD FIA FCIA FSA CFA
Senior Lecturer in Actuarial Science, University of Kent

Executive Summary

Introduction

Firefighters initially had a compulsory pension age of 60 years established by the Fire Brigades' Pensions Act 1925. This was lowered to 55 years for firefighters up to and including the rank of Station Officer (now Watch Manager B) by subsequent legislation. However the New Firefighters' Pension Scheme Regulations 2006 closed the 1992 scheme to new entrants and introduced a Normal Pension Age (NPA) of 60 years. The Hutton report of 2010 recommended that the Government should consider setting a NPA of 60 years as the benchmark for all Uniformed Services Schemes.

The Department of Communities and Local Government Firefighters' Pension Scheme: Heads of Agreement of 2012 includes a requirement for the NPA to be subject to regular review, informed by research carried out by the Firefighters' Pension Committee (FPC)..

All previous decisions on a pension age have been based on qualitative assumptions about fitness. No previous reviews have attempted to quantify the numbers expected to be fit leading up to and at the NPA. Other nations have a wide variety of pension ages for firefighters and there is no evidence that any of these nations have attempted a quantitative assessment of the evidence in order to determine a pension age based on physiology and medical fitness.

This paper reviews and analyses the evidence for changes in fitness with age, and for changes in prevalence of chronic disease with age. It quantifies these changes in order to produce a model that gives estimates for numbers likely to be aerobically fit at an NPA, both for firefighters who do not maintain physical fitness and body mass index as they age and for firefighters who do.

In order to create this model, a number of assumptions have been made, so the final figures given are estimates, not guaranteed numbers. The review has been provided with data from a substantial number of Fire Services, and the estimates produced fit well with the actual data.

This is not a political review of the changing approach to pensions, but a scientific review of the evidence of how capabilities change with age. The work has not been undertaken in isolation; it was essential that the UK Fire and Rescue Services (FRS) and firefighters were given an opportunity to comment and inform the authors. The FRSs have provided a wealth of data as well as advice on structures and roles. The Fire Brigades Union has also provided essential research papers, data and comment. Richard Stevenson has collected and provided data from a number of the FRSs, and wrote Chapter 10. It is important to recognise the part that everyone has played in producing this work, but also to recognise that the summary and conclusions are made by the primary authors alone. The additional members of the review board have contributed greatly, but this paper does not represent their opinions and they have not endorsed the findings or the recommendations.

Cardiorespiratory fitness

The most important consideration is physical fitness for role. In order to produce definitive answers, the FRSs must have a defined fitness standard or standards. It does not yet have any clearly defined and universally agreed standard(s). A study is currently in progress, sponsored by the Chief Fire Officer's Association, to develop clear measurable standard(s) but this will not report until 2013/4. Meanwhile a number of FRSs use an aerobic fitness standard that estimates a firefighter's maximum rate of oxygen uptake (VO_2max), a universally recognised measure of aerobic fitness. The general standard used by many FRSs is a minimum fitness level of 42 $mL \cdot kg^{-1} \cdot min^{-1}$, while some adopt an 'at risk' standard of 35 $mL \cdot kg^{-1} \cdot min^{-1}$ where firefighters are allowed to continue on operational duties for a limited period while they undergo remedial fitness training. This review has taken 42 $mL \cdot kg^{-1} \cdot min^{-1}$ for the aerobic fitness benchmark for the recommendations, but specifically does not endorse this as a recommended standard for firefighting, and acknowledges that aerobic fitness is only one component of total firefighter physical fitness. The recommendations of this review are therefore provisional until clear standard(s) are developed, encompassing strength and muscular endurance requirements as well as aerobic fitness requirements.

Studies show that below an aerobic fitness standard of 42 $mL \cdot kg^{-1} \cdot min^{-1}$ the risk of sudden catastrophic cardiac events increases, and below the level of 35 $mL \cdot kg^{-1} \cdot min^{-1}$ the increase is significant, with a risk of sudden death particularly while undergoing high levels of physical exertion. There is a strong argument that FRSs have a duty of care to their firefighters and to the general public to minimise this risk by maintaining an appropriate and safe level of aerobic fitness.

Physical fitness is known to decline with age. Studies show that without regular physical activity this decline is substantial and progressive from age 20. A model developed from a number of major academic studies estimates that for the general male population, around 60 % of men meet the standard of 42 $mL \cdot kg^{-1} \cdot min^{-1}$ at age 25, but this drops to 35 % at age 35, 15 % at age 45 and less than 1 % at age 60. Within these studies, it is shown that the small subgroup (<25 %) that could maintain weight and physical activity levels would maintain a mean fitness of above 42 $mL \cdot kg^{-1} \cdot min^{-1}$ to age 70, assuming they start with a VO_2max above 49 $mL \cdot kg^{-1} \cdot min^{-1}$ at 25 years. The drop in fitness seen in the general population is mostly due to unhealthy lifestyle choices, weight gain and lack of physical activity.

A number of recent studies have suggested that firefighters are no fitter than the general population. They are as overweight as the general population, but have fewer individuals in the higher category of obesity than the general population. Our modelling of research papers combined with our limited data from the FRSs shows that UK firefighters are physically fitter than the general population, with an estimated mean VO_2max of ~ 50 $mL \cdot kg^{-1} \cdot min^{-1}$ being maintained until 35 years of age.

The models estimate the number of firefighters who will be unable to meet the minimum aerobic fitness standard as they age. In the worst case scenario, where firefighters follow the normal population changes in physical activity levels and body mass index with ageing, 85 % would be unfit for duty at 55 years, increasing to 92 % at 60 years. In the best case scenario, where firefighters maintain their physical activity levels and body mass index as they age, 15 % would be unfit at 55 years, increasing to 23 % at 60 years. Those who fall below the standard at ages 55 and 60 years are likely to have been close to 42 $mL \cdot kg^{-1} \cdot min^{-1}$ when joining their FRS. It is up to individual FRSs to decide how to manage individuals who fall below their selected fitness standard. Current practice in many FRSs is to allow them to continue on duty 'at risk' while undertaking remedial training, and the great majority are able to increase their fitness levels to the appropriate standard within a few months.

Recent data collected from four FRSs found at 50-54 years of age, 51 % (n=417/822) of firefighters were below 42 $mL \cdot kg^{-1} \cdot min^{-1}$. At 55-60 years, 66 % (n=70/106) of firefighters were below this minimum standard.

Fitness in women is significantly lower than for men at all ages; however the decline in fitness follows a similar rate when activity levels and body mass index changes are similar. The same model can therefore be used for both sexes for the decline in aerobic fitness. There will however be fewer women with a substantially higher starting fitness than the minimum standard required, so more women are likely to drop below the required aerobic fitness standard as they age.

Firefighters in management roles of Station Manager and above have less requirement for a high level of operational fitness, and no significant problems with fitness are expected in relation to age in this group, assuming a recommended minimum VO_2max standard of 25 $mL \cdot kg^{-1} \cdot min^{-1}$ is required in the role.

Strength

There is no compulsory strength standard for selection to the FRS, and in order to develop a benchmark for the review, the ladder lift test from the National Firefighter Selection Test was used as a standard. The model for strength change with age was developed from studies of grip strength and assumed no additional physical training. The model showed that by age 55, 10 % of men and 30 % of women would fail the test, and by age 60 the figures would be 20 % and 40 % respectively. These figures would be expected to reduce significantly if a policy of routine physical training which included strength training was adopted across all Fire Services.

Medical health

A medical model was produced for the most important chronic medical conditions likely to affect fitness for firefighting across the age range 45-75 in the general population. Ill health retirement (IHR) data for 2007-12 from 38 FRSs were then compared with predictions from the model. The IHR data demonstrated that firefighters are substantially healthier than the general public. This would be explained by the significantly fewer very obese firefighters than in the general population and the higher levels of aerobic fitness. Increasing the NPA from 55 to 60 is expected to result in an additional 30-40 IHRs assuming there are 5000 firefighters in the age range 55-59. There are expected to be substantially more firefighters with chronic disease who have not reached a point where IHR is appropriate. Assuming 120 firefighters with chronic disease who are not fully fit, this would represent 2.5 % of age group 55-60.

Structural implications, reasonable expectations and management issues

A final decision on the implications of the appropriate NPA can only be made when a decision is made on minimum fitness standard(s). If a fitness training programme is adopted across all FRSs, this may require additional fitness advisers and may have minor implications in relation to overall manning levels. The increase in numbers medically unfit, and in IHR numbers, is not expected to have a substantial effect on operational effectiveness.

There will be a significant number of firefighters who expected to retire at age 55 and will have difficulty maintaining fitness beyond this age. Among those who have joined on the 2006 pension scheme there will also be some who will have difficulty maintaining fitness, and there are likely to be around 2.5 % who are medically unfit above age 55 but who do not meet the criteria for IHR. There is likely to be a substantially larger proportion of women firefighters who are physically and/or medically unfit over age 55. Allowing firefighters to leave after age 55 on a pension that is actuarially reduced from age 60 without any additional penalty could be considered a reasonable way to manage expectations, and to manage any potential discriminatory issues.

Recommendations

Fitness standard(s). It is essential to determine minimum role-related fitness standard(s) across the UK FRSs.

Fitness selection at recruitment. FRSs should consider informing applicants that those whose fitness is close to 42 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ are unlikely to maintain fitness to NPA unless they are able to increase their level of physical activity and/or reduce their body mass index.

Fitness assessments. All FRSs should conduct regular fitness assessments for all firefighters to ensure fitness for role is maintained.

Fitness training. All FRSs should implement regular fitness training. We recommend 2.5 hours a week of fitness training should be incorporated into the daily routine of whole time firefighters. Appropriate support and opportunities for fitness training should be provided for retained firefighters.

Early leavers. Firefighters over the age of 55 who can no longer meet the fitness requirement could be allowed to leave early on an actuarially reduced pension. The pension should be calculated so there is no overall financial advantage or disadvantage to the firefighter (or to the pension scheme) from the member leaving before the NPA. This would help address any equality issues in relation to women firefighters and disabled firefighters.

Ill health retirement. In order to avoid any advantages to IHR, those who become permanently medically unfit for firefighting below age 55 could take their pension early at the same rates as those who leave early because they are unable to meet the fitness requirement.

Ill health retirement for a qualifying injury. Where a firefighter becomes permanently medically unfit for firefighting because of a qualifying injury, the current arrangements outlined in the New Firefighter Pension Scheme Regulations 2006 should continue.

Ill health retirement data collection. All FRSs should routinely collect IHR data annually, to include as a minimum the age, role, gender, medical diagnosis and duration of service of the firefighter. An appropriate body should be identified to collect and analyse the data and report annually on their findings.

Fitness data collection. All FRSs should routinely collect fitness data annually; the specific data to be collected should be determined by the current review into fitness standards. An appropriate body should be identified to collect and analyse the data and report annually on their findings.

Further NPA reviews. The next review should be undertaken once fitness standard(s) have been determined and sufficient data have been collected to measure the effect of implementing these standards. It is unlikely that the review will have sufficient data until at least 2016.

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1 Background

1.1 Why review the pension age?

1.1.1 The Fire Brigades Pensions Act 1925 established the first national retirement age for firefighters, and it was compulsory at age 60 for all ranks. It was later reduced to age 55 for firefighters up to and including the rank of Station Officer (now Watch Manager B). By the time of the 1973 Firefighter Pension Scheme 55 was established as a compulsory retirement age for firefighters up to the rank of Station Officer and 60 for those in the rank of Assistant Divisional Officer (now Station Manager) and above. The ages selected were not based on any quantitative medical or physiological evidence or research.

1.1.2 Changes in life expectancy, demographics and economic pressures have lead to a Government decision to review public sector pension schemes in the early part of the last decade. From 1 April 2006 the 1992 Firefighter Pension Scheme was closed to new entrants and a new scheme (the New Firefighters Pension Scheme 2006) was introduced with a Normal Pension Age (NPA) of 60. In addition to new starters, from that date the scheme was opened up to retained firefighters who were unable to join the 1992 scheme. Currently in England around 5,000 whole time firefighters and over 7,000 retained firefighters belong to the 2006 scheme, and over 80% of firefighters are members of a firefighter pension scheme. Both schemes provide for staff to retire on a non-actuarially adjusted pension at NPA. The 1992 scheme allows its members to retire from age 50 provided they have 25 years of service. The 2006 scheme allows staff to access their pension below age 60 on the grounds of permanent ill health, or on the grounds of efficiency of the service when aged 55 or over, or from age 55 with an actuarial reduction (usually considered to be around 5%) calculated from age 65.

1.1.3 In 2010, the Government wished to put public service pension schemes on a long-term sustainable footing. As a result Lord Hutton chaired a Government review of public sector pensions with a view to achieving long-term reform and reduced overall costs. The Hutton Report included recommendations on uniformed services pensions, and in the executive summary the Commission stated that the NPA for the 2006 Firefighters Pension Scheme of 60 should be the benchmark for all Uniformed Services Schemes (Hutton, 2011):

1.1.4 'The key design feature contained in this report should apply to all public service schemes. The exception is the case of the uniformed services where the NPA should be set to reflect the unique character of the work involved. The Government should therefore consider a new NPA of 60 across the uniformed services. Where the NPA is currently below this level in these schemes it should keep this under regular review.'

1.1.5 The Commision's findings and recommendations were based on the NPA being established at 60 in the 2006 Firefighters Pension Scheme. The Department of Communities and Local Government (DCLG) Firefighters' Pension Scheme: Heads of Agreement (Department of Communities and Local Government, 2012) (, Firefighters' Pension Scheme: Heads of Agreement - Fire and emergencies - Department for Communities and Local Government) includes the requirement for the NPA to be subject to regular review, and that the review will be informed by research carried out by the Firefighter's Pension Committee (FPC). A scoping report on the NPA was undertaken for the Fire Brigades Union (FBU) in 2011 (Graveling and Crawford, 2011c). Following this, a formal review paper has been commissioned by the FPC in order to inform the FPC and DCLG and consider the evidence to support the appropriate NPA for firefighters.

1.1.6 There are a number of factors to be assessed when considering an appropriate NPA. These include:

- The current NPA of staff and the predicted retirement rates.
- The identification of appropriate fitness standards or requirements for firefighters.
- The age limit at which current serving firefighters can achieve these standards or requirements without any intervention.
- The age limit at which current serving firefighters can achieve these standards or requirements with intervention (such as regular physical training, lifestyle change etc.).
- Whether different NPA structures may be appropriate given the requirements of differing roles.
- What this intervention might involve.
- Whether this intervention, and /or any age change, is reasonable for the employer and tax payer.
- Whether current serving firefighters are able to engage with the necessary intervention to achieve any increase in age limit.
- Whether new selection criteria might be needed to achieve a higher normal pension age.

1.1.7 Some of these issues are medical and physiological, some are social and political. The Terms of Reference for this paper have included elements of both.

1.2 Terms of reference

1.2.1 This is to be an objective review to:

- consider the evidence to support the appropriate NPA for firefighters
- consider the structural implications for the proposed scheme of such recommendations (single age or range, likely numbers across range of ages).
- be mindful of the reasonable expectation that scheme members will be able to work to, and retire at, the NPA.

- take account of the economical, efficient and effective management of the fire service, the changing profile of the workforce and the occupational demands of, and fitness standards for, firefighting roles.

1.2.2 To undertake an objective review of the currently available evidence for:

- The job requirements
  - Occupational demands
  - Fitness Standards
  - Roles
- The implications of the job requirements in terms of physiological standards
  - Aerobic fitness
  - Muscular strength and endurance
  - Body size and composition
  - Heat tolerance
  - Shiftwork
- The evidence base for achievable fitness levels and capacity
- The evidence base for current levels and capacity including workforce profile changes.
  - To include a review of current firefighter age and fitness profiles, and reasons for early retirement.
- The evidence base for the impact of medical conditions on fitness with age.
- Any additional requirements related to equality issues and geographical variance.
- Current practice elsewhere.
- Any additional economic factors.

1.2.3 Suggest likely structures for a scheme.

1.2.4 Suggest areas of additional work that might be required.

1.3 The focus of this review

1.3.1 This report will primarily focus on the physiological and medical issues. It will comment on the social and political issues, including reasonable expectations, management matters, and workforce profile, and will suggest possible structures. It will be for DCLG to determine any final structure on the basis of the evidence from this report. Gender issues will be considered throughout. Currently less than 1% of wholetime firefighters work beyond age 55 (Department of Communities and Local Government, 2011); there is therefore very little experience of UK firefighters working beyond age 55 to inform the report, and evidence has to be sourced from elsewhere.

1.3.2 The report is primarily a review of the literature. It will also consider data available from current national research projects being undertaken. Additional data were provided by the Fire and Rescue Services both in relation to fitness and ill health retirement. The FBU has also contributed their own 22 page submission to inform the review (Fire Brigades Union, 2012).

1.3.3 The report will look generally at issues that affect pension age, so although the review was prompted by an increase in NPA from 55 to 60 for the majority of members, the age beyond 60 will be considered in part to provide a physiological and medical context for age 60. This also allows for the fact that many studies have relatively wide age groups, so it is important to look either side of the age range 55-59 in order to get an understanding of the trends, and it acknowledges that some firefighters, particularly retained firefighters, already serve beyond age 60 and will wish to do so in future.

1.3.4 The responsibility for Fire and Rescue Service Policy has been devolved to the respective Nations, so this report on behalf of the DCLG will primarily focus on England. There are obvious parallels with the other Nations, and in many cases there will be either no difference or no separate data for other Nations, so the evidence may at times refer to UK populations, and at times to different Nations. It will include statistics on Scotland, Wales and Northern Ireland where the information is of value to the overall discussion. Clearly, population differences will follow gradients across borders, so differences for example in Scotland are likely to affect firefighters in Northern England.

1.4 Who does this review affect?

1.4.1 As at 31 March 2011, around 23,500 firefighters in England were members of the Firefighters Pension Scheme 1992 (FPS). Current plans for the scheme are for the 10,500 firefighters in the FPS over the age of 45 to have transitional protection arrangements to keep their NPA of age 55 (which in practice allows most to retire in their early 50s), those 4,800 aged between ages 41 and 45 will receive tapered protection retiring between ages 55 and 60 (some earlier if they have completed 25 years service), leaving around 8,200 firefighters who will be expected to continue working until they are age 60 if they are to have an unreduced pension (Frequently Asked Questions on Reforms to the Firefighters’ Pension Scheme, 2012). Most of this latter group joined on the understanding that they would retire at age 55 on a full pension. Any decision on increasing the NPA must also consider the fairness in relation to this group. A YouGov survey in May-June 2011 asked FBU members for their opinions on an increase in NPA to 60, 18 % of FBU members participated, 90% strongly opposed the plans and a further 7 % tended to oppose them (FBU, 2011). The FBU are concerned that, having noted improvement in the quality of the service following good progress in recruiting more women, an increase in NPA could unfairly affect women in the service (Fire Brigades Union, 2012).

1.5 Previous work

1.5.1 There has been one previous study involving an evidence-based approach to setting the pensions age for firefighters in the past. This was undertaken by Haisman for the Home Office Fire Research and Development Group in 1996 (Haisman, 1996b). This summarised the available literature, concluding that there was no reason to change from a retirement age of 55. The review quantified a standard, and the fitness of the firefighting population, in effect measuring the status-quo. The review noted the fact that firefighters were then no fitter than the general population, and that they would therefore have increasing difficulty achieving the required fitness standard as they got older, and that more might succumb to chronic disease above the age of 55. It did not quantify the effect of reduced fitness and chronic disease. It suggested that attention should be paid to fitness and medical surveillance but it did not suggest what the outcomes might be if Fire Brigades implemented fitness strategies with the aim of improving overall fitness relative to age. The approach can perhaps be summarised by the paragraph which states 'Retaining the existing age of retirement at 55 years should be considered. This option has attractions, most notably that it appears to work and is in line with the majority of comparable organisations in this country and some in Europe.' The conclusion was qualitative rather than quantitative, with no attempt to apply figures or statistics to a final age recommendation.

1.5.2 A scoping study was commissioned by FBU in 2011 and undertaken by Graveling and Crawford (Graveling and Crawford, 2011c). This found little clear evidence in the literature to inform the discussion on pension age and concluded that older firefighters will find the demands of being a firefighter more taxing than their younger counterparts. The study was qualitative with no attempt to quantify the effect of age.

1.5.3 If this report were to follow the same approach as Haisman, it is likely to come to much the same conclusions. If firefighters do not do any more exercise than the general population and live similar lifestyles they will become unfit for firefighting at a relatively young age, and they will succumb to chronic diseases at around the same age too. We should be mindful of the progressive decline in fitness within the general population over the past few decades that is predicted to continue.

1.5.4 This report intends to review the available data and where possible to give quantitative answers in relation to age. It will ask different questions. Are firefighters as unfit as the general population? Will this substantially affect their ability to work longer? If the situation can change how can this be reasonably achieved?

1.6 The role of firefighters

1.6.1 Firefighters work in a wide variety of roles, and progression up the ranks also leads to a significant change in operational roles and expectations. The primary concern of this report is those roles requiring higher levels of fitness. The best representative role was assumed to be entering and fighting a compartment fire wearing breathing apparatus (BA).

1.6.2 Career progression does lead to a variation in role, and a clear demarcation is seen on progression from Watch Manager where there can still be a requirement to work 'on the pump' and wear BA in a compartment fire, and ranks above this where it would be very unusual to need to wear BA in a compartment fire, and while some Fire and Rescue Services still consider the ability to wear BA to be a core requirement for senior officers, the fitness requirement would not be the same for senior ranks. A decision was therefore taken to divide the roles into 'on the pump' roles of the ranks including and below Station Manager, and the more senior 'off the pump' management roles.

1.6.3 An important consideration is not just how tough firefighting might be, but how often do firefighters have to work at intense levels of activity? On the one hand, a standard is needed to benchmark the requirement for fitness; on the other hand recovery time may also need to be taken into account if there are frequent exposures to intense activity. Where exposure to the most extreme activities is rare, a balance might be needed between availability of recruits and retirement age for example in rural areas where the few available volunteers are in their late 50s or 60s, or even 70s.

1.6.4 The Cunningham report in 1971 concluded that time spent on fighting fires represented between 3 and 10 percent of a firefighter's total time (Cunningham, 1971). An Audit Commission report *In the Line of Fire* estimated it in 1995 as between 5 % and 10 % (Audit Commission, 1995). Time spent at intense levels of activity will only be a small proportion of time spent attending fires. Firefighter roles have continued to change over the last fifty years and are still changing. The Bain review recommended a shift from fire fighting to fire prevention, and this has in turn led to a shift in workload and role (Bain et al., 2002).

1.6.5 Most of the literature referring to the role of firefighters emphasises the arduous nature of the role. There is no doubt that firefighters working on an operational task will work as hard as they can. Just because a standard may be set at a VO_2max of 42 $mL{\cdot}kg{\cdot}min^{-1}$ does not mean they will limit their effort to this; if their own VO_2max happens to be 75 $mL{\cdot}kg{\cdot}min^{-1}$, they will work towards this level However in order to ensure that the role can be assessed objectively, only the standard can be used as the benchmark. If a firefighter meets the standard they are fit for duty, whether they are aged 20 or 80, man or woman.

1.7 Methodology

1.7.1 Database searches were undertaken for the medical and health aspects of the study using Medline, Embase, Pubmed, and general searches of Google Scholar and Google for documents. This review was not intended to be a systematic meta-analysis of data; the scope of the report is too wide to make this a realistic proposition. Good analyses have already been done in many areas; in others the available evidence is insufficient to conduct a meaningful higher level statistical analysis of studies but sufficient to inform this report. Where available, reviews rather than individual papers were selected. Search terms included firefighter, fireman, fire service, fire personnel, smoke jumper and emergency service personnel. Search terms also included age, obesity, ischaemic heart disease, cardiovascular disease, stroke, cancer, colon cancer, lung cancer, breast cancer, prostate cancer, spine, back, hip, knee, shoulder, osteoarthritis, mental health, anxiety, depression, common mental disorders, PTSD, disability, work, employment, physical fitness and shiftwork.

1.7.2 In most areas reviewed, narrow database searches resulted in few useful studies, and the reviewers had to widen the search in most cases to include documents not available using the standard search engines, and use experience and judgement to identify other sources. Sources of morbidity and mortality data were identified, where possible, from National archives and Government-sponsored studies.

1.7.3 In many cases where data were presented in age groups, the groups selected were wide. Some statistical extrapolation was therefore required to separate data out into narrow age groups in order to distinguish between 50-54 years and 55-59 year groups. No useful mathematical tool could be identified to model this with any of the data sets, so the authors had to resort to drawing lines and reading off graphs to provide the final numbers. It is important to appreciate that although this represented the best available method of arriving at meaningful numbers there is a potential wide margin of error in all the statistics presented.

1.7.4 The core part of the review was the development of models for predicting decline in fitness with age, decline in strength with age, and change in disease prevalence with age. This enables us to predict the likely impact of an increase in retirement age with actual numbers for the first time. These models show the effect of a choice of different fitness standards and the potential impact of fitness training.

1.7.5 Ethical approval was provided by the Staff and Research Centres' Research Ethics Committee, Centre for Health Services Studies, University of Kent. It was recognised that the main concern was to ensure anonymity of data. No individual fire and rescue services have been identified. Care has taken when analysing small groups of ill health retirement data against age so that individuals could not be identified. Age has been considered in five-year ranges and data for women has been included with men for specific conditions because numbers for women were so small.

1.8 Statistics: use and analysis of data

1.8.1 This review has been undertaken by scientists using scientific approaches and analaysis of available evidence. It has to follow scientific principles and express the discussions and findings in scientific language. Many readers will not have a scientific background. Statistics can be challenging for all of us, and it is worth considering some key points for those wishing to read the whole document and understand all the issues.

1.8.2 Percentages can often be confusing, so wherever possible, the differing rates expressed in other studies (percentages, numbers per million or per 100,000) have been converted to numbers per thousand population. This helps put the figures in context; one person having heart disease in every thousand firefighters can be easier to comprehend than a rate of 0.1 %.

1.8.3 Where there is a change, this is wherever possible expressed as a percentage change. It is important to distinguish between a percentage that is constant, and a change on that percentage with age. For example in any one year 30% of firefighters of any age may experience back pain. If 30% of firefighters aged 55-59 experience back pain, there is no difference between them and any other age group. A 10 % increase in back pain in the age group 55-59 would represent an increase from 30 % to 33 %. This 3 % would be 30 firefighters in every 1000.

1.8.4 Where the original effect studied is small, even a large percentage change on this may also be small and therefore insignificant. To give an example, if someone offers to double your money (a 100 % increase), this could be a generous offer. It does, however, depend on what money they are doubling. If they refer to the money in your bank account and you have £1000 in it, they will be giving you another £1000. If, however, they are only referring to the £50 in your wallet, they will be giving you another £50. If you have no wallet and only have 5 pence in the lining of your jacket you will only get 5 pence. In all cases they are doubling your money, but the amount you get may be a very substantial £1000 or a very insignificant 5 pence. If someone finds that firefighters assisting in flood relief have an increased risk of 100 % of being struck by lightning, this does not mean that this is a very significant risk for firefighters. If the original risk of a firefighter in UK being struck by lightning while attending a flood was one firefighter every 10 million years, and this risk increases to two every ten million years, the risk overall is still insignificant.

1.8.5 Where the original study is based on very small numbers, the strength or power of that study is relatively small. It is unreliable. Some academic papers may only be based on a study of 50 firefighters, so we may not be able to learn a great deal from these; a paper studing 50,000 firefighters will be much more significant. Sometimes the only information we have is based on one small study, so although we may acknowledge it we may not be able to rely on it as a basis for future policy. For example, the data we received from fire and rescue services indicated that 13 firefighters were ill health retired with heart disease between 2007-12. None were from Northern Ireland. This does not mean that no firefighter in Northern Ireland gets heart disease. Population statistics from Northern Ireland actually suggest that the prevalence of heart disease in Northern Ireland is higher than in England, so we have to accept that the IHR data on heart disease is unrepresentative. It is accurate because it is based on actual figures, but we cannot rely on it to predict future heart disease rates in Northern Ireland.

1.8.6 Readers may well be surprised by the differing sources of data. Wherever possible, UK data have been used because we are studying UK firefighters. In many cases, there are no UK based studies available that have looked at the issues we are concerned with, and we have had to look overseas. In some cases there are only one or two studies worldwide, so we have had to take studies from elsewhere such as USA, Japan, Finland and Australia. We recognise that these may not be ideal, but they represent the best available evidence we could find. The assumption is that a Japanese knee is no different to an English knee; an Australian spine is no different to an English spine and so on. Had this study been undertaken ten years ago, it would have been very difficult as there was substantially less published data of relevance. A review in five or ten years time is likely to have much more useful data available. The results of a future review may well therefore be different. That is progress. We have used what is available now, knowing that future studies may well result in different advice and change in policies.

1.9 Use of terminology and confidentiality

1.9.1 Terminology can often be an issue, and we are aware that there will be sensitivities and concerns. The term Fire Services will be used generally to refer to organisations that might otherwise be called Fire and Rescue Services or Fire Brigades. The terms ‘men firefighters’ and ‘women firefighters’ will be used throughout when discussing specific gender issues.

1.9.2 Individual references to Fire Services have been avoided where possible. We are very grateful to those who provided data and wish to respect their anonymity. Where anonymous examples have been used in the text these are all fictitious and any resemblance to serving or retired firefighters or Fire Services is unintentional.

1.10 The approach from other Fire Services

1.10.1 Comparison between the UK Fire and Rescue Service and fire services in other nations is not straightforward. The UK has a high proportion of full-time firefighters, very few volunteers or industrial firefighters and no routine input from the military. In the Netherlands only 20 % of firefighters are full time while 80% are volunteers. In Denmark only 20 % are full time, 50 % part-time and the remainder are volunteers.

1.10.2 Mandatory retirement ages used to be very common, but many countries are removing them for the same reasons as UK. Some countries still have them in place but most are adopting a more flexible approach. In USA there is a mandatory retirement age of 57 unless the firefighter has less than 20 years of service. Mandatory retirement in Canada is prohibited from December 2012 but Canada has until recently had a normal retirement age of 60 for career firefighters and age 65 for volunteer firefighters.

1.10.3 Belgian firefighters currently retire at 58 but there are plans to increase this to 67.   In 2006 the retirement age for firefighters in Austria was 55-60, it was 63 in the Czech Republic, 60 in Denmark, 65 in Estonia, 63-68 in Finland, 60 in Germany, 55 in Greece, 55 in Ireland, 60 in Italy, 55 in Luxembourg, 55 in Netherlands, 60 in Norway, 65 in Portugal, 62 in the Slovak Republic, 55 in Slovenia, and 65 in Spain (EPSU, 2006).

1.10.4 While most countries appear to have a lower retirement age than for the general population, the variation in ages selected, the variation in roles, and the lack of any evidence-base for age selection makes comparisons unhelpful. This review will not therefore take into account any particular approach from overseas.

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2 Firefighter Roles, Occupational Demands and Physical Requirements

David M. Wilkinson, Victoria L. Richmond and Mark P. Rayson

2.1 Firefighter roles

2.1.1 The roles and responsibilities of the UK Fire and Rescue Service are evolving, and adjusting to changes in risk (Rayson, 2004), but there remains a requirement to fulfil its traditional role to extinguish fires and protect life and property in the event of a fire (Fire and Rescue Services Act, 2004). Although the need for firefighters to respond to extreme events of this nature may be rare, the core requirements of firefighting remain physically demanding.

2.1.2 In 2004 a review reporting the medical and occupational evidence for recruitment and retention in the Fire and Rescue Service (Rayson, 2004) identified 18 discrete roles within the Service. Seven of these firefighting (non-control) roles are identified within the Integrated Personal Development System (IPDS) that supports the Fire and Rescue Service to train and develop its staff to meet the changing demands that face the service. These seven firefighting roles were broadly clustered into a predominantly operational (fire appliance) based role and a predominantly management based role (Table 2.1), although it is acknowledged that there will be some regional variation within this structure.

Table 2.1 Firefighting Roles within the Fire and Rescue Service

	Clustered Roles (Rayson, 2004)	
	Predominantly Operational (Appliance) Fire Role	**Predominantly Management Role**
Discrete Firefighter Roles	Firefighter Crew Manager Watch Manager	Station Manager Group Manager Area Manager Brigade Manager

2.2 Occupational demands

2.2.1 Rayson (2004) performed a questionnaire based high level job analysis of these firefighting roles, using 1057 responses from 4000 questionnaires which were distributed to all 58 Fire and Rescue Services within the United Kingdom. Critical tasks were identified for each role, and cluster analysis revealed six relevant activity categories within the operational and management roles. These six activity categories were found to comprise a ‘physical’ component and a ‘psycho-social’ component. Table 2.2 shows a summary by clustered role of each activity requirement, with the constituent activities and tasks within each activity category. Table 2.2 shows that the ‘operational’ cluster role has a high requirement for movement, strength tasks and coping with challenging environments, and a very high requirement for using self-contained breathing apparatus. This is in contrast to the ‘management’ cluster role, which rates the requirement on each of these activities as low and a more important emphasis is placed on the psycho-social components of addressing groups and operational pressures.

2.2.2 Optimal Performance Limited (Rayson et al., 2004a) has previously reviewed the literature to identify the physical tasks that UK Fire and Rescue Service operational personnel are likely to be required to perform at some time during their career. Table 2.3 provides a brief summary of the studies reviewed, highlighting the key fire and rescue scenarios and/or physical tasks identified.

2.2.3 Optimal Performance Limited addressed this issue as part of their work programme to develop and validate new National Firefighter Selection Tests (NFSTs) for the Fire and Rescue Service (Rayson et al., 2009a). This work was guided and endorsed by a Steering Group comprising key stakeholders including the Chief Fire Officer’s Association (CFOA), the Local Government Authority (LGA), the Fire Brigades Union (FBU), Networking Women in the Fire Service, the Black and Ethnic Minority Members section of the FBU (BEMM) and the Association of Local Authority Medical Advisors (ALAMA). Around 30 Fire and Rescue Services contributed actively to the development of the work by supplying subject matter experts, hosting workshops and contributing participants to the various studies involved in the process.

2.2.4 Following a workshop held at the Fire Service College in June 2002, five firefighting scenarios were identified as being the most physically demanding aspects of the firefighter role: a domestic fire search and rescue scenario, a domestic fire salvage scenario, a rural fire scenario, a road traffic accident scenario and an enclosed breathing apparatus search scenario (Rayson et al., 2009a). These scenarios were very similar to the key tasks that had previously been identified in the peer reviewed literature (Table 2.3).

2.2.5 After a long process of development, refinement, and practical experience, six key physically demanding tasks and standards were endorsed by the NFST Steering Group, reflecting the physical requirements needed to be a safe and effective firefighter. A summary of these tasks and the standards set by the Steering Group is shown in Table 2.4.

Table 2.2 Summary requirement of activity categories by clustered role (Rayson, 2004)

	FIREFIGHTING ACTIVITY CATEGORIES					
	Physical Components				**Psycho-social Components**	
Category and Constituent Activities and Tasks	**Movement:** Sprinting, Running, Jogging, Walking, Climbing stairs, Climbing ladders, Crawling, Jumping, Hammering, Digging	**Strength** Lifting more than 5kg, 10kg, 20kg, 40kg Carrying more than 5kg, 10kg, 20kg, 40kg Pushing/pulling more than 5kg, 10kg, 40kg	**Environment** Fire compartment temperatures above 100°C, Elevated temperatures (30-100°C), Freezing temperatures (sub-zero), Dust, Overcrowding, Open spaces, Height, Enclosed spaces, Total darkness, Partial darkness, Working in water, Working under water, Handling hazardous substances, Smoke, High humidity	**SCBA** Using Self Contained Breathing Apparatus	**Addressing Groups** Addressing groups of people	**Operational Pressure** Dealing with traumatised victims, Dealing with traumatised others (e.g. relatives, public), Making critical decisions quickly
CLUSTERED ROLE						
Operational (Firefighter, Crew Manager, Watch Manager)	High	High	High	Very High	High	Very High
Management (Station Manager, Group Manager, Area Manager, Brigade Manager)	Low	Low	Low	Low	Very High	Moderate

SCBA is self-contained breathing apparatus, Rating scale: None, Low, Moderate, High, Very High

Table 2.3 Summary of studies defining key UK Fire and Rescues Service physical scenarios and/or tasks

	Key Tasks
Love et al., (1996)	Shipboard firefighting, searching for casualty, casualty rescue, BA wear, lifting and carrying in CBRN PPE, ladder ascent descent
David et al., (1997)	Hose, ladder, pump and carry and rescue drills. Road traffic accident drills, water relay drills and breathing apparatus drills
Brewer (1999)	Firefighting (domestic, car, basement, garage, ship, high rise), road traffic incidents
Implementation Working Group (2000)	Aerobic fitness requirement (shuttle running), dead lift, ladder extension, hose running, ladder ascent and descent, breathing apparatus work in enclosed space
Oldham et al., (2000)	Under running a 9 m ladder, team lift and carry of a light portable pump, returning 13.5 m ladder to the appliance, hauling an extended line on a 13.5 m ladder
Eglin et al., (2004)	Casualty rescue (50 kg)

Table 2.4 A summary of the key physical tasks and standards used to validate the National Firefighter Selection Tests (Rayson et al., 2009a)

Task Name	Brief Description	Standard
Rural Fire Criterion Performance Test	Wearing firefighting turnout clothing: Hose drag (50 m) from drum on appliance Walk/Jog back 50 m Carry 2 x 70 mm coiled hose 200 m Run out 2 x 70 mm hose over 2 x 25 m (50 m) Walk/jog back 150 m Carry 100 mm suction hose and basket 200 m Walk/Jog 200 m Carry light portable pump simulator (33 kg) 200 m	13 minutes
Domestic Fire Criterion Performance Test	Wearing firefighter turnout clothing and BA under air: Hose drag 30 m 30 m casualty carry/drag (30 kg) Walk 10 m, rest 30 s (obscuration mask fitted) Crawl 20 m 30 m casualty carry/drag (55 kg)	4 minutes
Ladder Lift Criterion Performance Test	Wearing firefighter turnout clothing: Lift a 13.5 m ladder simulator from 75 cm to 1.82 m	30 kg
Ladder Climb Criterion Performance Test	Wearing firefighter turnout clothing: Climb 13.5 m ladder to 3rd floor Return to the ground (not timed)	40 seconds
Ladder Extension Criterion Performance Test	Wearing firefighter turnout clothing: Fully extend a 13.5 m ladder (pawled to 9th round) Lower the ladder back under control	14 seconds
Enclosed Space Criterion Performance Test	Wearing firefighter turnout clothing and BA under air, fitted with obscuration mask: Negotiate through an 80 m^3 modular crawl way, passing over/through 8 obstacles	7 minutes

BA is breathing apparatus

2.2.6 Further work in the development of fitness standards and suitable tests to manage fitness issues is currently in progress through a collaboration between the Chief Fire Officers Association, The FireFit Steering Group and the University of Bath (Stevenson, 2012). A recent (October 2012) job analysis workshop hosted by the project team asked expert panel members to identify the most physically demanding tasks performed by station based firefighters, with the following results:

- Wearing breathing apparatus in live fire situations
- Stair climbing / working / carrying equipment in high rise structures
- Using equipment at road traffic collisions

- Swift water rescue / mud rescue
- Casualty evacuation
- Hose carrying / manipulation (particularly in confined space / compartments)
- Wild land fire (especially on hilly terrain / long grass)
- Using / wearing gas tight suits (but not as hard as other tasks described above).

2.2.7 While the specific detail of the physical tasks involved in performing these simulations is yet to be determined, it is worth noting that, with the exception of the swift water/ mud rescue scenario and gas tight suit wear, all other tasks and simulations are encompassed in the NFST simulations described in Table 2.4. While the Fire & Rescue Service is changing the way in which it responds to fire risk, elements relating to the physically demanding aspects of the job appear to remain similar over time (Tables 2.3 and 2.4). As long as firefighters are required to protect lives and property through aggressive firefighting activities, the role will maintain an element of physicality.

2.3 Physical requirements

2.3.1 It is evident from the job simulations described in Table 2.4 that it is difficult to isolate the individual components of physical fitness (e.g. muscular strength or cardiorespiratory endurance) required to successfully perform critical firefighting tasks. However, it is also clear that different combinations of cardiorespiratory endurance, muscular strength, muscular endurance, speed, power and agility are required in some measure (Rayson et al., 2009a, Rayson et al., 2004a, Rhea et al., 2004, Henderson et al., 2007b, Williford et al., 1999, Michaelides et al., 2011). Despite the multidimensional nature of the physical fitness components required for safe and effective firefighting, previous research studies have almost exclusively focused on defining a minimum cardiorespiratory requirement for task completion. Table 2.5 shows a summary of the oxygen cost of performing various firefighting tasks or scenarios.

2.3.2 There are several points to draw out from Table 2.5. Clearly, the oxygen cost for firefighting activities is highly variable, depending on the nature and duration of the task, the speed at which the task was performed (self-paced or best effort), the personal protective equipment worn, the breathing apparatus carried, the equipment carried and/or used, and the fitness of the firefighters undertaking the task (Table 2.5).

2.3.3 The rates of oxygen uptake (VO_2) for firefighting activities range from 23 $mL \cdot kg^{-1} \cdot min^{-1}$ (mean) during a boundary cooling task (Bilzon et al., 2001b) to ~44 $mL \cdot kg^{-1} \cdot min^{-1}$ (peak) during heavy equipment carry or casualty rescue tasks (Holmer and Gavhed, 2007, Bilzon et al., 2001b, von Heimburg et al., 2006). It is important to remember that these values are group mean results, and individual variation around this mean is large. For example, during a firefighting simulation that had a mean VO_2 requirement of 34 $mL \cdot kg^{-1} \cdot min^{-1}$ and a peak requirement of 44 $mL \cdot kg^{-1} \cdot min^{-1}$, the individual values ranged from 26–43 $mL \cdot kg^{-1} \cdot min^{-1}$ and 34–55 $mL \cdot kg^{-1} \cdot min^{-1}$ respectively (Holmer and Gavhed, 2007).

2.3.4 The peak VO_2 demands are typically sustained for less than 10 minutes, and can equate to relative exercise intensities of ~ 80-85 % VO_2max in well trained firefighters (Dreger and Petersen, 2007, Bilzon et al., 2001b, von Heimburg et al., 2006, O'Connell et al., 1986). Although participants in most studies wear full personal protective equipment (PPE) and carry breathing apparatus during the simulations, only recently has the oxygen uptake measuring equipment been integrated into the breathing apparatus so the tasks can be performed “under air” (Williams-Bell et al., 2010b, Williams-Bell et al., 2010a). Not using breathing apparatus during simulations may result in an underestimation of the true relative exercise intensities reported, as recent work suggests that VO_2max may be reduced by ~ 17 % when using breathing apparatus, due to limitations in maximum ventilation rates imposed by the respiratory equipment (Dreger et al., 2006).

2.3.5 When considering the aerobic energy requirements of these firefighting tasks, and taking into account the relative exercise intensity that can be sustained for typical firefighting activities, several authors have recommended a minimum aerobic fitness standard (VO_2max) for safe and effective firefighting. These recommendations range from 33 $mL \cdot kg^{-1} \cdot min^{-1}$ (Sothmann et al., 1990), 39 $mL \cdot kg^{-1} \cdot min^{-1}$ (O'Connell et al., 1986), 41 $mL \cdot kg^{-1} \cdot min^{-1}$ (Bilzon et al., 2001b, Sothmann et al., 1990), 42 $mL \cdot kg^{-1} \cdot min^{-1}$ (Dreger et al., 2006), 45 $mL \cdot kg^{-1} \cdot min^{-1}$ (Gledhill and Jamnik, 1992a), to as high as 52 $mL \cdot kg^{-1} \cdot min^{-1}$ (Gledhill and Jamnik, 1992b).

2.3.6 It is important to note that measuring VO_2 only quantifies the aerobic energy contribution to the task, and the total energy required to complete these activities is substantially greater due to a significant additional anaerobic energy contribution (Bilzon et al., 2001b, Lemon and Hermiston, 1977, Perroni et al., 2010). Hence, simply quantifying the oxygen requirement of firefighting tasks will only partly quantify the physical demands of these activities.

2.3.7 The importance of muscular strength, muscular endurance and body composition for successful performance on many firefighting tasks should not be underestimated, especially those tasks that involving heavy lifting and/or carrying (e.g. casualty rescue). The importance of these components of fitness to physical performance for firefighting is discussed in Chapters 3 (body composition) and Chapter 5 (muscular strength and endurance).

2.3.8 When carrying an absolute load, the resultant physiological strain becomes greater for lighter people than for their heavier peers (Bilzon et al., 2001a), and the relative increase in strain is greater as the load becomes heavier (Holmer and Gavhed, 2007). This explains why the absolute measurement of VO_2max ($L \cdot min^{-1}$) is a superior predictor to relative VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$) for firefighting tasks involving heavy loads and /or equipment. Von Heimburg et al. (2006) showed that compared to relative VO_2max, absolute VO_2max discriminates faster firefighters during a stair climbing (and repeated casualty rescue scenario).

2.3.9 More recently, absolute VO_2max has been shown to be the best predictor of the US Candidate Physical Ability Test for firefighters, with relative VO_2max showing a much weaker or no relationship with firefighting performance (Williams-Bell et al., 2009, Sheaff et al., 2010). The outcomes from the development of the National Firefighter Selection Tests supported these studies, where estimated absolute VO_2max ($L \cdot min^{-1}$) was the best predictor of performance on the rural fire criterion performance test and the domestic fire criterion performance test (Rayson et al., 2009a, Rayson et al., 2009b).

2.3.10 Acceptance of this finding was one of the practical reasons why the NFST Steering Group elected to adopt a job simulation approach (rather than gym-based fitness tests) for selecting firefighting applicants, as job simulations involving load carriage with a fixed pass time elicit different relative physical demands depending on individual body size (Bilzon et al., 2001a). The alternative approach of using physical performance tests to measure specific components of fitness that relate to job performance, e.g. the multistage fitness test to estimate VO_2max (Ramsbottom et al., 1988), would result in individuals of different body mass requiring different pass standards to achieve the same performance on the firefighting task. For example, to pass the NFST rural fire criterion performance tests, a 50 kg individual would need a predicted VO_2max of 42 $mL \cdot kg^{-1} \cdot min^{-1}$, in comparison to a 100 kg individual who would only need to achieve a VO_2max of 33 $mL \cdot kg^{-1} \cdot min^{-1}$ for the same rural performance time (Rayson et al., 2009b). Thus, it is not possible to accurately define a single relative VO_2max standard ($mL \cdot kg^{-1} \cdot min^{-1}$) for role related physical fitness tests.

2.3.11 The recommended aerobic fitness levels required for firefighters vary widely, typically ranging from 33–45 $mL \cdot kg^{-1} \cdot min^{-1}$. However, many of these recommendations were based on the physiological responses to best effort performance on well trained firefighters, and did not assess the minimum aerobic requirement for safe and effective firefighting on these tasks. Further, as none of the recommended aerobic fitness standards are based on UK Fire and Rescue Service personnel performing tasks at the minimum pace required for safe and effective firefighting, their direct relevance for UK Fire and Rescue Service personnel is questionable.

2.3.12 Although work is currently underway to address this issue (Stevenson et al., 2009), the only validated and legally defensible fitness standards that can be recommended for UK Fire and Rescue personnel at present are those used during the development of the NFST (Rayson et al., 2009a) – see Table 2.4. The findings from this work suggest that the required aerobic fitness (VO_2max) standard for the most aerobically demanding simulation (the rural fire simulation) ranges from ~33-42 $mL \cdot kg^{-1} \cdot min^{-1}$, depending on body size (Rayson et al., 2009b).

2.3.13 The FireFit[a] Steering Group currently recommends a common aerobic fitness standard of 42 $mL \cdot kg^{-1} \cdot min^{-1}$ for safe and effective firefighting performance, with firefighters being withdrawn from operational roles when their VO_2max falls below 35 $mL \cdot kg^{-1} \cdot min^{-1}$ (Stevenson et al., 2009). Although not all Fire and Rescue Services

[a] The FireFit Steering Group provides a forum to identify, develop, communicate and promote best practice pertaining to fitness related health issues of the UK Fire and Rescue Service (www.firefitsteeringgroup.co.uk)

have adopted these two aerobic fitness standards for the firefighting role, and while this review is not endorsing any aerobic fitness standard, the 42 $mL \cdot kg^{-1} \cdot min^{-1}$ standard will be used in the Section 4.2 to model the impact of ageing on aerobic fitness levels and its impact on the estimated number of firefighters fit for duty.

2.3.14 For those firefighters in predominantly management roles who attend live incidents and may wear BA but are unlikely to actively fight the fire (Station Managers and above – see Table 2.1), the estimated VO_2 demand while performing low levels of physical activity (e.g. walking in full PPE with breathing apparatus) range from ~ 15 $mL \cdot kg^{-1} \cdot min^{-1}$ (Taylor et al., 2011, Dreger and Petersen, 2007) to 25 ± 5 $mL \cdot kg^{-1} \cdot min^{-1}$ (Williams-Bell et al., 2010b). Assuming an average demand of ~ 20 $mL \cdot kg^{-1} \cdot min^{-1}$ and a requirement for this demand to be approximately 80 % VO_2max to allow a safety margin (Bilzon et al., 2001b, Gledhill and Jamnik, 1992a, Gledhill and Jamnik, 1992b), the cardiorespiratory demand for fire and rescue personnel performing this type of management role would be approximately 25 $mL \cdot kg^{-1} \cdot min^{-1}$.

2.3.15 Again, while this review is not endorsing any aerobic fitness standard for Fire and Rescue Service management roles, the standard of 25 $mL \cdot kg^{-1} \cdot min^{-1}$ will be used in Section 4.2 to model the impact of ageing on aerobic fitness levels and its impact on the estimated number of Fire and Rescue Service managers fit for duty. If wearing BA at incidents is not an absolute requirement for individuals in these management roles, the suggested fitness requirement should be ignored.

2.4 Summary

2.4.1 The aerobic fitness requirements for UK Fire and Rescue Service personnel performing a predominantly operational (firefighting) role or a predominantly management role have been reviewed.

2.4.2 At present, the Fire and Rescue Service has not collectively adopted minimum aerobic fitness standards that would ensure safe and effective job performance in these two discrete cluster roles.

2.4.3 This review is not endorsing any aerobic fitness standards, and acknowledges the limitations of just using a discrete physiological measure (e.g. VO_2max) to quantify overall firefighting physical performance ability.

2.4.4 However, it will use a VO_2max of 42 $mL \cdot kg^{-1} \cdot min^{-1}$ for the firefighting role and 25 $mL \cdot kg^{-1} \cdot min^{-1}$ for the management role for the sole purpose of modelling the theoretical impact of ageing on aerobic fitness levels, and its impact on the estimated number of Fire and Rescue Service personnel fit for duty (see Chapter 4).

Table 2.5 Summary of studies measuring the cardiorespiratory requirements during typical firefighting tasks and/or scenarios

Reference	Participants	Task	Results ($ml \cdot kg^{-1} \cdot min^{-1}$)	Comments
Lemon et al., (1977)	20 M Canadian Firefighters	Fire kit but no breathing apparatus Ladder climb Casualty rescue Hose drag Ladder raise	29 (mean) 30 (mean) 31 (mean) 27 (mean)	Tasks (31-100 s) performed at designated "firefighting speed". Estimated VO_2 cost due to duration of tasks at 60-80 % VO_2max Participants >40 $mL \cdot kg^{-1} \cdot min^{-1}$ may supply more of energy cost aerobically
O'Connell et al., (1986)	17 US Firefighters	Stair climbing in kit and breathing apparatus	39 ± 3 (mean)	60 x 8 inch steps per min on stair climbing machine wearing 39 kg PPE required 80 ± 9 % VO_2max. VO_2 range 32-44 $mL \cdot kg^{-1} \cdot min^{-1}$ Require at least 39.0 $mL \cdot kg^{-1} \cdot min^{-1}$ or 2.7 $L \cdot min^{-1}$
Sothmann et al., (1990)	136 M US Firefighters	Simulation wearing breathing apparatus Stair climb Room search Casualty rescue (68 kg) Pulls on pike pole Down and up stairs with 23 kg pump Forced entry with axe Pulls on pike poll	31 ± 6 (mean)	Self selected pace. VO_2 range 24-49 $mL \cdot kg^{-1} \cdot min^{-1}$ and 76 ± 8 % VO_2max (range 59-94 %). Duration 9 ± 2 min (5.5-13.9 min) Proposed > 33.5 $mL \cdot kg^{-1} \cdot min^{-1}$ standard, although 41 $mL \cdot kg^{-1} \cdot min^{-1}$ allows reserve
Sothmann et al., (1991)	10 M US Firefighters	Simulation wearing breathing apparatus Stair climb Room search Casualty rescue (68 kg) Pull on pike pole Down and up stairs with 23 kg pump Forced entry with axe Pull on pike poll	31 ± 7 (mean)	8 ± 2 min (5.5-13.9 min). VO_2 range 24-49 $mL \cdot kg^{-1} \cdot min^{-1}$ or 73 ± 10 % VO_2max (range 54-88 %)
Sothmann et al., (1992)	10 M US Firefighters	Fire emergency	26 ± 9 (mean)	Estimated from heart rate VO2 relationship. Duration 15 ± 7 min (8-28 min). 63 ± 14 % VO_2max (range 44-86 %)

Gledhill et al., (1992a)	Canadian Firefighters	Simulation with PPE and breathing apparatus (22 kg) Carrying equipment (49 kg) upstairs	41.5 (mean)	Range 37-44 mL·kg^{-1}·min^{-1} Recommended 45 mL·kg^{-1}·min^{-1} standard, based on 41.5 mL·kg^{-1}·min^{-1} for 10 min with BA at 85 %VO_2max and allowing for 4 % measurement error to give applicant "benefit of potential error"
Lusa et al., (1993)	35 Firefighter trainees	Ship: Entry into smoke filled room with kit and breathing apparatus	31 ± 6 (mean)	17 ± 4 min. Estimated VO_2 2.4 ± 0.5 L·min^{-1} and 60 ± 12 % VO_2max
Bilzon et al., (2001b)	49 (34 M; 15 W) UK Royal Navy	Shipboard firefighting tasks: Drum carry (30 kg) up/down stairs Extinguisher carry ~ 11 kg Boundary cooling (BC) - 10 kg hose Hose run (HR) 16 x 12.3 m ~ 7 kg each Ladder climb (LC) with 10 kg hose	 43 ± 6 (mean) 39 ± 4 (mean) 23 ± 6 (mean) 38 ± 5 (mean) 38 ± 5 (mean)	Paced at minimum acceptable standard for 4 min Recommend 41 mL·kg^{-1}·min^{-1} standard, assuming mean demand of 33 mL·kg^{-1}·min^{-1} (for BC/HR/LC wearing 23 kg PPE) for 20-30 min would require ~ 80 % VO_2max
Petersen et al., (2004)	25 (13 M; 12 W) Canadian Firefighters	Not specified but assume full PPE Search 8 blacked out smoke filled rooms on two floors with charged hose before double casualty rescue	27 ± 3 (mean) 35 ± 5 (peak)	Men faster (11 vs 14 min) mainly due to casualty drag at end. No gender difference for VO_2
Von Heimberg et al., (2006)	14 M Norwegian Part-time Firefighters	Fire kit and breathing apparatus Stair ascent 6 floors with 37 kg total load Casualty rescue (6 x 80 kg)	 34 ± 4 (mean) 44 ± 5 (mean)	As fast as possible Task 6.5 ± 1 (range 5-9 min) Peak VO_2 64 ± 7 % VO_2max Peak VO_2 83 ± 7 % VO_2max Large heavy firefighters faster than smaller ones. Recommended VO_2max of 4 L·min^{-1}. Hence, VO_2max of ~ 66 mL·kg^{-1}·min^{-1} for 60 kg individual and ~ 40 mL·kg^{-1}·min^{-1} for 100 kg individual.

Dreger et al., (2007)	53 (30 M; 23 W) Canadian firefighters and civilians	Fire kit and breathing apparatus (23 kg) Hose carry (16.5 kg) Ladder carry (13.6 kg) and raise Hose drag (require ~260 N) Ladder climb Rope pull (required ~200 N) Forced entry using 4.5 kg hammer Casualty rescue (68 kg) Ladder Climb Ladder lower (13.6 kg) and carry Spreader Tool carry (36 kg)	42 ± 4 M (mean) 35 ± 4 F (mean)	Simulation lasted ~ 6 ± 1min (~4 min working and ~2 min recovery). The test was best effort. Men and women worked at same ~85 ± 7 % VO_2max, but men 17 % faster (fastest woman quicker than 56 % men) Faster performance related to higher VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$) - estimated VO_2 of 34.1 $mL \cdot kg^{-1} \cdot min^{-1}$ to meet 8 minute performance standard. Hence, a VO_2max of 40 $mL \cdot kg^{-1} \cdot min^{-1}$ would be required
Holmer et al., (2007)	15 M Swedish Firefighters	Fire kit and breathing apparatus (22 kg) Walk/run Stair ascend and descend Tunnel crawl Walking running Carrying equipment Repeat some of above (11 tasks in all)	44 ± 6 (peak) 34 ± 4 (mean)	Performed as quickly as possible. Mean 22 ± 3 min (range 16-28 min). Mean VO_2 range 26-43 $mL \cdot kg^{-1} \cdot min^{-1}$ and peak VO_2 range 34-55 $mL \cdot kg^{-1} \cdot min^{-1}$.
Elsner et al., (2008)	20 M US Firefighters	Fire kit and breathing apparatus (27 kg) Advancing hose (41 kg) Carrying 33 kg ladder and extension Advancing hose (82 kg) up stairs Forced entry using 4.5 kg hammer Stair climbing Rope pull of hose up 3 floors Hose advance through cluttered area Stairs descent and ascent with 23 kg hose Casualty rescue (75 kg)	29 ± 8 (mean) 32 ± 11 (end)	Fast as possible but replicating fire scenario: 11.7 ± 2 min (range 8-17 min). Task completed at 62 ± 10 VO_2max.
Williams-Bell et al., (2009)	46 (32 M; 14 W) Canadian civilian volunteers	Fire kit and weighted vest (23 kg) Candidate Physical Ability Test 3 min Stair climb with 11.3 kg load Hose drag and hose pull Ladder raise and extension Forced entry with 4.5 kg hammer Tunnel search Casualty rescue (75 kg) Pike pole	~38 ± 5 (mean)	Best effort performance test ~ 72 ± 8 % VO_2max. Duration ~8-11 min. Assuming 10:20 min:s standard, requires 3.5 $L.min^{-}1$ VO_2max. Hence, VO_2max of ~ 58 $mL \cdot kg^{-1} \cdot min^{-1}$ for 60 kg individual and ~ 35 $mL \cdot kg^{-1} \cdot min^{-1}$ for 100 kg individual.

Perroni et al., (2010)	20 M Italian Firefighters	Fire kit and breathing apparatus (23 kg) Ladder climb Stair descent with 20 kg casualty Run 250 m Tunnel search for exit Run 250 m	38± 7 (peak)	Quickly as possible 90 ± 14 % VO_2max. Duration ~12 ± 2 min
Williams-Bell et al., (2010a)	36 (33 M; 3 W) Canadian Firefighters	Fire kit and breathing apparatus (18 kg) High rise stair climb with 18 kg pack Search and rescue Stair climb with 18 kg pack Room search advancing uncharged hose Forced entry Casualty rescue (75 kg) Stair descent	38 ± 5 (mean) 34 ± ~5 (mean)	Both tasks self paced at "Normal work effort". VO_2 measurement integrated with breathing apparatus. VO_2 range 25-47 $mL \cdot kg^{-1} \cdot min^{-1}$ or 75 ± 8 % VO_2max (range 58-91 %). Duration 10 min (range 8-14 min). VO_2 range 23-42 $mL \cdot kg^{-1} \cdot min^{-1}$ or 67 ± 10 % VO_2max (range 46-87 %). Duration 5.5 min (range 4-9.5 min).
Williams-Bell et al., (2010b)	36 (33 M; 3 W) Canadian Firefighters	Fire kit and breathing apparatus (18 kg) Simulated subway rescue Descend stairs carrying 22 kg pack Approach walk (290 m) Ladder step Carriage search Casualty rescue (75 kg) Retreat walk Ascend stairs	24 ± 5 (mean) 30 ± 5 (peak)	Self paced at "typical fire scene work rate". VO_2 measurement integrated with breathing apparatus. ~ 12 ± 1 min (range 10-13.5 min) VO_2 range ~20-40 $mL \cdot kg^{-1} \cdot min^{-1}$ and 47 ± 8 % VO_2max (peak 60 ± 10 %)

M is men, W is women, PPE is personal protective equipment, BA is breathing apparatus

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3 Body Composition and Ageing

Victoria L. Richmond, David M. Wilkinson and Mark P. Rayson

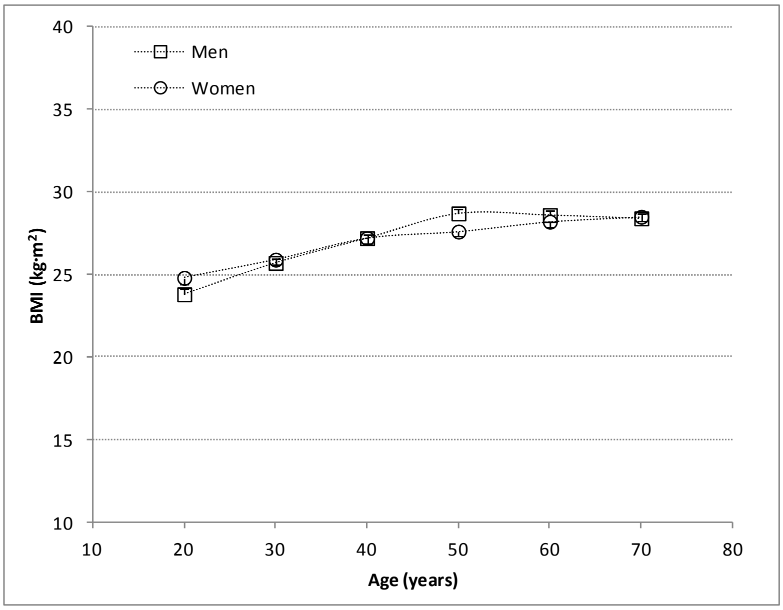
3.1 Literature search

3.1.1 This review on the impact of ageing on firefighting performance will concentrate primarily on the affect on aerobic fitness, and muscular strength and endurance. The changes in body mass and body composition that are observed with increasing age will be discussed in this section. However, it is not the changes in these physical parameters *per se* that are of importance, rather the concomitant affect these changes will have on physical performance. Muscular strength is dependent to a large extent on absolute muscle mass (Kenny et al., 2008), with body fat being less important in determining ability to perform a static lift. Tasks requiring aerobic fitness and muscular endurance in firefighters are usually load-bearing for which muscle mass is also an important determinant of performance. Additionally, levels of body fat are also important in the more aerobic based tasks because the firefighter does not want to be carrying excess “dead” mass. A firefighter who gains body fat will increase the metabolic demand of a task, requiring him to work harder to maintain the same exercise intensity. In addition, body composition plays a large role in determining the health and safety of the firefighter, not only critical for personal well-being, but also for the safety of their fellow firefighters and the public (Smith et al., 2012b). However, this will be discussed in other chapters relating to the risk of disease with increasing age.

3.1.2 This chapter provides a short summary of changes in body composition with age, with normative data from a cohort of UK firefighters. This information can also be drawn on in latter chapters when changes in physical performance and health parameters are discussed. Typically body mass gradually increases to the age of anywhere between 40 years (Allied Dunbar National Fitness Survey, 1992a, Janssen et al., 2000) and 60 years (Jackson et al., 2012), and on the whole this increase in body mass is due to an increase in fat mass (Atlantis et al., 2008, Allied Dunbar National Fitness Survey, 1992a). Loss of muscle mass (termed sarcopenia) occurs around the age of 55 years (Booth et al., 1994), and is often associated with a decline in body mass (Atlantis et al., 2008, Jackson et al., 2012).

3.1.3 Body mass index (BMI) describes an individual’s body mass relative to their height, and using the World Health Organisation classification system individuals’ level of obesity can be described. A National Health Survey for England reported the annual BMI of children and adults in private households in England (National Health Service, 2010); data for the year 2009 are shown in Figure 3.1. For men BMI peaks at age 50 and for women it continues to increase to age 70 years. A caveat must be included when using BMI data to describe the body composition and obesity for a given population. Body mass index fails to take into account levels of body fat or lean mass; thus a muscular sportsman may be classified as obese due a high body mass, whereas his level of fat could actually be fairly low. A study by Romero-Correl (2008) tested the correlation between lean mass, body fat and BMI in over 13,000 volunteers. The results concluded that the accuracy in BMI for diagnosing obesity is limited, particularly for those in the intermediate categories. While one can be fairly certain that someone with a BMI of >30 kg·m^2 is in fact obese, many of those under 30 kg·m^2 will also have obese levels of body fat.

Figure 3.1 Mean body mass index (BMI) for England (National Health Service, 2010)



3.1.4 Normative data from a selection of UK Fire and Rescue Services including currently serving firefighters have been provided by individual Services. Table 3.1 shows the mean body mass and BMI for firefighters within five year age categories, as well as the percent of individuals in that group, for men and women firefighters respectively. Table 3.2 shows the body fat (%) for a sub-group of that cohort. Similar to the general population, BMI gradually increases in firefighters over time. Figure 3.2 shows the body mass data graphically so the changes with ageing are easier to observe. There is a gradual increase in body mass with ageing for the male firefighters by approximately 10 kg between the ages of 20 and 50 years, after which body mass tends to stabilise. There is also a general trend for an increase in body mass for women firefighters[b] by about 5 kg between the ages of 25 and 50 years.

3.1.5 Body fat was measured for a proportion of this cohort (165/227 women and 4713/7550 men) and those data are shown in Figure 3.3. This figure shows that the changes in body mass are mirrored by the changes in body fat in men firefighters, suggesting that the gradual increase in body mass with ageing is due to an increase in body fat. For women firefighters, although it would appear that body fat remains fairly stable with increasing age, the data from the first two age categories (<20 years and 20-24 years) cannot be reliably used to observe a trend as there were only one and two women in each category respectively. If those two categories are ignored, the relationship between body fat and body mass remains the same for women, with an overall increase between the ages of 25/30 years to age 55 years. However, with such a small cohort (a maximum of 25 participants per age group) it

[b] The data point at age 20 is that of just one Firefighter and as such is not representative of that age group. This data point should be disregarded for the purposes of observing a trend with ageing.

would be unreliable to suggest that this is representative of the entire population of women firefighters.

Table 3.1 Physical characteristics (body mass and body mass index; BMI) of firefighters from four Fire and Rescue Services

	Men		**Body mass (kg)**	**BMI (kg·m^2)**	**Women**		**Body mass (kg)**	**BMI (kg·m^2)**
Age	**N**	**Percent (%)**	**Mean ± SD**	**Mean ± SD**	**N**	**Percent (%)**	**Mean ± SD**	**Mean ± SD**
<20	19	0.3	79.7 ± 14.1	24.3 ± 3.1	1	0.4	73	26
20-24	218	2.9	82.8 ± 12.6	25.7 ± 3.3	8	3.5	64.9 ± 12.3	24.3 ± 3.6
25-29	727	9.6	82.7 ± 11.5	25.7 ± 3.0	30	13.2	69.1 ± 15.5	24.0 ± 4.4
30-34	1195	15.8	84.2 ± 10.7	26.0 ± 2.8	69	30.4	65.9 ± 8.5	23.5 ± 2.8
35-39	1230	16.3	85.2 ± 11.4	26.7 ± 3.1	41	18.1	70.0 ± 11.8	24.5 ± 3.0
40-44	1555	20.6	88.3 ± 12.1	27.6 ± 3.2	49	21.6	69.2 ± 8.9	24.5 ± 3.2
45-49	1674	22.2	89.6 ±12.8	28.0 ± 3.4	25	11.0	68.9 ± 10.2	23.8 ± 3.4
50-54	818	10.8	88.7 ± 12.0	27.9 ± 3.4	4	1.8	75.5 ± 12.2	25.9 ± 2.9
55-59	106	1.4	89.7 ± 13.5	28.3 ± 3.8	0	0	N/A	N/A
60-64	8	0.1	86.9 ± 13.3	27.6 ± 3.4	0	0	N/A	N/A

Table 3.2 Body fat (%) of firefighters from one Fire and Rescue Service

	Men		**Body fat (%)**	**Women**		**Body fat (%)**
Age	**N**	**Percent (%)**	**Mean ± SD**	**N**	**Percent (%)**	**Mean ± SD**
<20	1	0.0	14.0	0	0	N/A
20-24	58	1.2	18.6 ± 5.7	2	1.2	30.5 ± 2.1
25-29	441	9.4	19.4 ± 5.4	18	11.0	27.2 ± 6.9
30-34	822	17.4	20.1± 5.2	57	34.5	26.8 ± 6.7
35-39	767	16.3	21.7 ± 9.2	25	15.2	30.1 ± 5.4
40-44	945	20.1	23.4 ± 5.5	36	21.8	28.7 ± 6.7
45-49	1091	23.1	24.7 ± 5.5	22	13.3	29.7 ± 5.5
50-54	542	11.5	25.4 ± 5.4	4	2.4	31.8 ± 6.2
55-59	47	1	26.3 ± 5.9	0	0	N/A
60-64	3	0.1	25.3 ± 5.5	0	0	N/A

Figure 3.2 Change in body mass at 5-year intervals of age

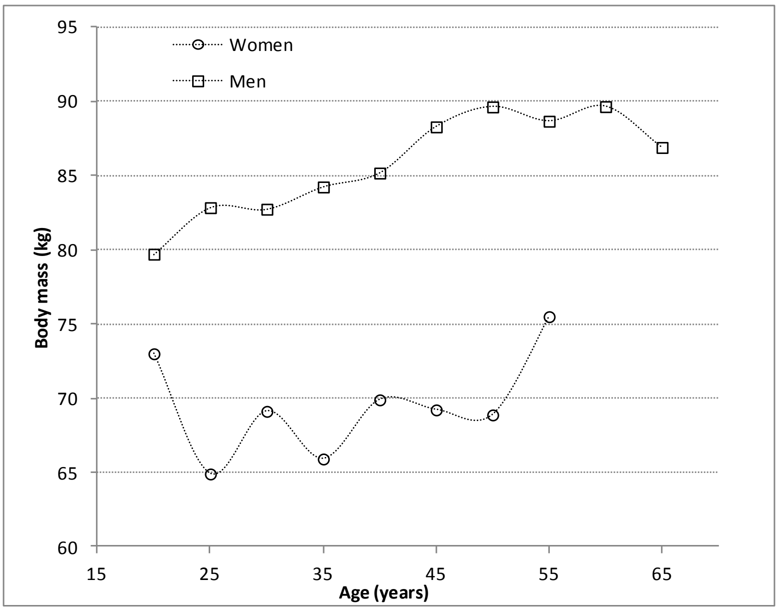
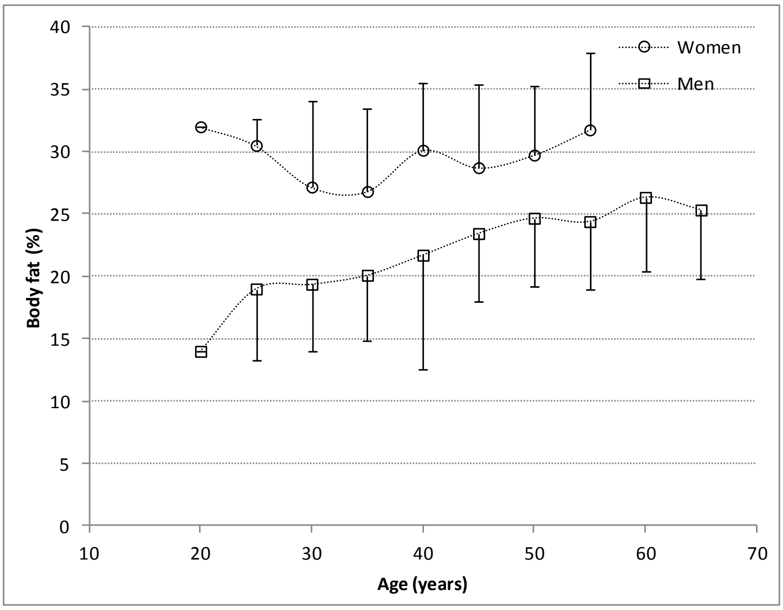


Figure 3.3 Changes in body fat (%) at 5-year intervals of age



3.2 Summary

3.2.1 In the general population, body mass rises with age due to an increase in fat mass, peaking somewhere between age 40 and 60 years

3.2.2 In the general population, following the peak in body mass, a decline is observed with ageing, usually due to a loss of lean mass

3.2.3 A sample of ~8000 UK firefighters shows a trend for body mass to gradually increase to age 55 years. This rise in body mass is associated with an increase in body fat.

3.3 References

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4 Effects of Ageing on Cardiorespiratory Fitness in Firefighters

David M. Wilkinson, Victoria L. Richmond and Mark P. Rayson

4.1 Literature search

4.1.1 To address the question, "how does cardiorespiratory fitness change with age", MEDLINE, the U.S. National Library of Medicine's bibliographic database of over 19 million references to journal articles in life sciences and biomedicine, was searched using PubMed. A clinical queries search using the categories 'prognosis' and 'narrow' and the search terms 'ageing AND exercise AND fitness' returned 57 results in the clinical study category. After applying the filters for written in English, species human, and published between 1990 and 2012, 52 studies remained. Studies were excluded if they did not allow the estimation or direct determination of relative levels of cardiorespiratory fitness (i.e. VO_2max in $mL \cdot kg^{-1} \cdot min^{-1}$) across the age ranges, did not include an age range spanning ≥18 but ≤ 25 years to ≥ 60 years, knowingly included individuals with chronic disease or mental illness, or did not have a gender specific sample size of at least 100 individuals. Two studies remained (Fleg et al., 2005, Jackson et al., 2009).

4.1.2 Known key national sources of normative data on changes in cardiorespiratory fitness with ageing were also reviewed: the Allied Dunbar National Fitness Survey (Allied Dunbar National Fitness Survey, 1992a), the Health Survey for England 2008 (Health Survey for England 2008, 2009) and the American College of Sports Medicine's Guidelines for Exercise Testing and Prescription (Thompson et al., 2010). In addition, past reports relating to physical fitness and/or pension age in the Fire and Rescue Service were reviewed (Rayson et al., 2009a, Rayson et al., 2009b, Office of the Deputy Prime Minister, 2004, Graveling, 2011a, Graveling and Crawford, 2011a, Haisman, 1996a).

4.1.3 All relevant references cited in the reviewed papers, books and reports identified were also reviewed if they related to changes in cardiorespiratory fitness with age. One additional key study was identified (Shvartz and Reibold, 1990).

4.2 Cardiorespiratory fitness changes with age

4.2.1 Cardiorespiratory fitness is an important component of physical fitness, and is a key physical characteristic that contributes an individual's ability to perform some essential firefighting tasks (Chapter 2). The cardiorespiratory fitness requirements that underpin safe and effective firefighting performance have already been discussed, and range from 33–52 $mL \cdot kg^{-1} \cdot min^{-1}$, depending on the task (Section 2.3). This section examines the evidence describing the change in cardiorespiratory fitness levels (as measured by maximal oxygen update; VO_2max in $mL \cdot kg \cdot min^{-1}$ and $L \cdot min^{-1}$) with advancing age.

4.2.2 There are two approaches used to quantify the change in cardiorespiratory fitness with advancing age — cross-sectional and longitudinal.

Cross-sectional studies

4.2.3 The cross-sectional approach examines studies that estimate or measure VO_2max on a sample of different aged individuals on one occasion, and plot the mean VO_2max for groups of similar aged individuals across the age ranges investigated. Although numerous studies have adopted this cross-sectional approach, many are limited by relatively small sample sizes (<500), narrow age ranges and very specific population groups (e.g. masters athletes), making them susceptible to inherent bias (Hawkins and Wiswell, 2003).

4.2.4 However, there are several large sample cross-sectional studies that are frequently used to demonstrate the cross-sectional changes in cardiorespiratory fitness with advancing age (Allied Dunbar National Fitness Survey, 1992a, Shvartz and Reibold, 1990, Health Survey for England 2008, 2009, Thompson et al., 2010). These studies are summarised in Table 4.1 and graphically in Figures 4.1 and 4.2.

Figure 4.1 Cross-sectional decline in relative cardiorespiratory fitness levels (VO_2max expressed as $mL{\cdot}kg^{-1}{\cdot}min^{-1}$) with ageing

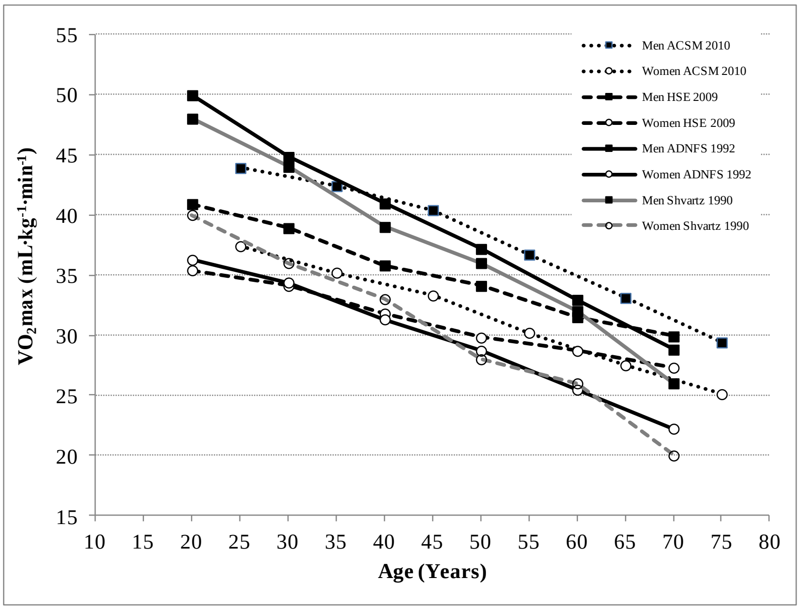


Figure 4.2 Change in relative cardiorespiratory fitness levels (VO_2max expressed as $mL{\cdot}kg^{-1}{\cdot}min^{-1}$) with ageing

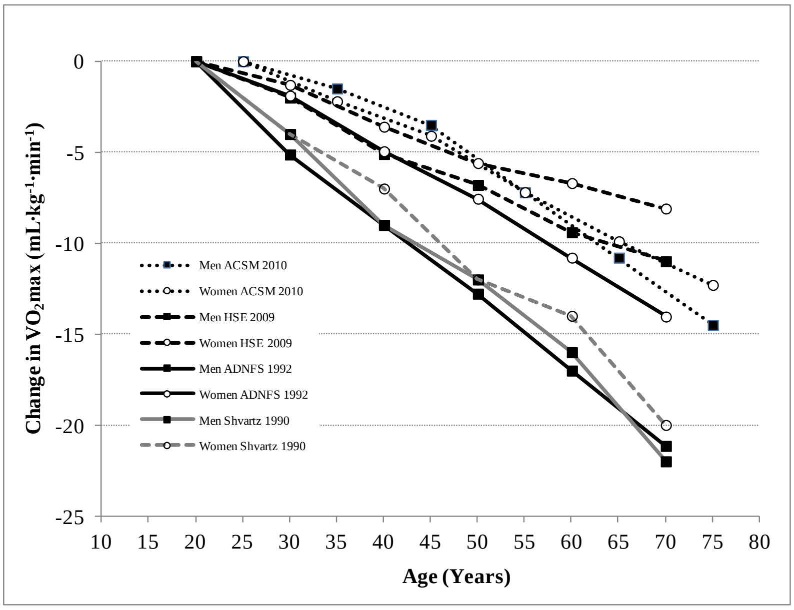


Table 4.1 Large sample cross-sectional and longitudinal studies examining the effect of ageing on VO_2max

Reference	Type of Study Design	Cardiorespiratory Fitness Measurement	Participants	Changes in Cardiorespiratory Fitness (VO_2max)	Other Findings/Comments
Shvartz et al., (1990)	**Cross-sectional** Cross-sectional analysis of 62 studies published up to 1986 from USA, Canada and 7 other European countries Each study had a sample of ≥6 participants in almost all cases, giving a total of 98 samples of men and 43 samples of women	Direct measurement of VO_2max using cycle and treadmill (no difference found between cycle and treadmill results so data combined)	Number not specified but ≥6 per sample and men n= 98 and women n=43 samples Healthy, untrained, sedentary or mildly active	**Men:** 20 yrs 47 $mL·kg^{-1}·min^{-1}$ – 70 yrs 26 $mL·kg^{-1}·min^{-1}$. Linear decline in VO_2max 0.42 $mL·kg^{-1}·min^{-1}$ per year **Women:** 20 yrs 40 $mL·kg^{-1}·min^{-1}$ – 70 yrs 19 $mL·kg^{-1}·min^{-1}$. Linear decline in VO_2max 0.41 $mL·kg^{-1}·min^{-1}$ per year	Relative ($mL·kg^{-1}·min^{-1}$) VO_2max of adult women is 19 % lower than that of adult men
Allied Dunbar National Fitness Survey (1992a)	**Cross sectional** From 5698 potential participants, only 53 % agreed to undertake a physical appraisal, and of those 3017, only 58 % (1741 participants) were able to complete the physical assessment (31 % of the total sample)	Predicted measurement of VO_2max from direct measurement of VO_2 and heart rate during uphill treadmill walking	Subsample of stratified sample of adult population of England aged 16–74 yrs spread across 30 parliamentary constituencies and 14 health regions **Men** n=858 **Women** n=883	**Men:** 20 yrs 50 $mL·kg^{-1}·min^{-1}$ – 70 yrs 29 $mL·kg^{-1}·min^{-1}$. Linear decline in VO_2max 0.42 $mL·kg^{-1}·min^{-1}$ per year **Women:** 20 yrs 36 $mL·kg^{-1}·min^{-1}$ – 70 yrs 22 $mL·kg^{-1}·min^{-1}$. Linear decline in VO_2max 0.28 $mL·kg^{-1}·min^{-1}$ per year	Reported values have been corrected for the reported overestimation of up to 10 %

Health Survey for England (2009)	**Cross sectional** From 3645 participants, only half agreed to undertake a physical appraisal, and of those, only 92 % (1693) completed the test (46 % of the total sample)	Predicted measurement of VO_2max using heart rate obtained on a step test	Random stratified sample of the 9 Government Office Regions of England **Men** n=806 **Women** n=887	**Men:** 20 yrs 41 $mL \cdot kg^{-1} \cdot min^{-1}$ – 70 yrs 30 $mL \cdot kg^{-1} \cdot min^{-1}$. Linear decline in VO_2max 0.22 $mL \cdot kg^{-1} \cdot min^{-1}$ per year **Women:** 20 yrs 35 $mL \cdot kg^{-1} \cdot min^{-1}$ – 70 yrs 27 $mL \cdot kg^{-1} \cdot min^{-1}$. Linear decline in VO_2max 0.16 $mL \cdot kg^{-1} \cdot min^{-1}$ per year	
Thompson et al., (2010)	**Cross sectional** Healthy volunteer participants enrolled on the Cooper Institute Aerobics Center Longitudinal Study in Dallas USA from 1970 to 2006; predominantly educated white, free from chronic disease	Predicted measurement of VO_2max using the final exercise intensity on a treadmill test to volitional exhaustion.	**Men** n=44549 **Women** n=14978	**Men:** 25 yrs 44 $mL \cdot kg^{-1} \cdot min^{-1}$ – 75 yrs 29 $mL \cdot kg^{-1} \cdot min^{-1}$. Linear decline in VO_2max 0.30 $mL \cdot kg^{-1} \cdot min^{-1}$ per year **Women:** 25 yrs 37 $mL \cdot kg^{-1} \cdot min^{-1}$ – 75 yrs 25 $mL \cdot kg^{-1} \cdot min^{-1}$. Linear decline in VO_2max 0.24 $mL \cdot kg^{-1} \cdot min^{-1}$ per year	Population is healthier than the total population due to 7 % of participants being excluded due to health risks

Fleg et al., (2005)	**Longitudinal** Healthy volunteer participant enrolled in the Baltimore longitudinal study of aging (from Baltimore-Washington USA) from 1978 to 1998; predominantly educated and white, without clinical coronary heart disease, other significant cardiopulmonary disease or major orthopaedic/neurological disability.	Direct measurement of VO_2max on a treadmill test to volitional exhaustion.	**Men** n=435 **Women** n=375 Median follow up period 7.9 years	For both men and women peak VO_2max ($mL{\cdot}min^{-1}$) remained stable from 20–40 years before progressively declining with increasing age. As body mass increased in both sexes until approximately 60 years, relative VO_2max ($mL{\cdot}kg^{-1}{\cdot}min^{-1}$) has an accelerated decline with increasing age, from ~5 % per decade at 20 yrs to over 20 % per decade at 70 yrs.	Relative ($mL{\cdot}kg^{-1}{\cdot}min^{-1}$) VO_2max of adult women is 17 % lower than that of adult men, although this reduced to <4 % when expressed relative to fat free mass Greater levels of habitual physical activity increase absolute VO_2max at any age, but do not prevent the accelerate decline with advancing age Accelerated decline in VO_2max with advancing age still occurs when controlled for changes in body composition
Jackson et al., (2009)	**Longitudinal** Healthy volunteer participants enrolled on the Cooper Institute Aerobics Center Longitudinal Study in Dallas USA from 1974 to 2006; predominantly educated white, free from chronic disease ~7 % excluded due to health risks	Predicted measurement of VO_2max using the final exercise intensity on a treadmill test to volitional exhaustion.	**Men** n=16889 **Women** n=3429 Median follow up period 4.0 years	See Figure 4.3 for the accelerating decline in VO_2max ($mL{\cdot}kg^{-1}{\cdot}min^{-1}$) with increasing age. Smoking, increasing BMI and decreasing habitual physical activity levels lower VO_2max for any age	Cross sectional analysis **Men** Linear decline in VO_2max 0.32 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ per year **Women** Linear decline in VO_2max 0.27 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ per year Relative ($mL{\cdot}kg^{-1}{\cdot}min^{-1}$) VO_2max of adult women is 16 % lower than that of adult men

4.2.5 Despite the variability in reported VO_2max between studies, it is clear that the large sample cross-sectional studies show that VO_2max progressively declines with age in a relatively linear fashion (Figure 4.1), with women having a 15-20 % lower VO_2max than men at a similar age (Shvartz and Reibold, 1990, Fleg et al., 2005, Thompson et al., 2010). When this linear decline is expressed as an absolute change in VO_2max from a starting age of 20-25 years, the rate of decline varies between 0.16–0.42 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ per year (Table 4.2).

4.2.6 Part of this large variability between the different rates of decline in VO_2max in cross-sectional studies is due to differences in lifestyle factors with ageing. A recent cross sectional study on 804 US career firefighters demonstrated that the age related decline in cardiorespiratory fitness levels can be attenuated by maintaining high (self-reported) levels of physical activity and a healthy body mass index (Baur et al., 2012a). Hence, differences in physical activity levels and BMI between the study populations reported in Table 4.1 will partly explain the differences in the relative VO_2max levels reported between studies (Figure 4.1), and likely account for a large proportion of the variability in the reported rate of decline in cardiorespiratory fitness level with ageing (Figure 4.2).

Longitudinal studies

4.2.7 Longitudinal studies estimate or measure VO_2max on a sample of the same individuals at different ages throughout their lifetime. Longitudinal studies provide a more accurate assessment of changes in cardiorespiratory fitness than cross sectional studies. Repeated sampling of each individual allows a statistical model of the age related decline in VO_2max to be produced that is independent of confounding variables such as physical activity levels and body mass index. Table 4.1 details the two recent large sample longitudinal studies that have modelled the age related decline in cardiorespiratory fitness levels (Fleg et al., 2005, Jackson et al., 2009).

4.2.8 Unfortunately the data reported by Fleg et al. (2009) only shows the change in relative VO_2max ($mL{\cdot}kg^{-1}{\cdot}min^{-1}$) from baseline (<30years) with ageing. However, the data do demonstrate that this rate of decline in VO_2max accelerated from ~ 2 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ per decade at 20-30 years of age, to ~ 6-7 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ per decade over 70 years of age (i.e. the decrease over time is not linear as has been reported in cross sectional studies). The study also concluded that the accelerated rate of decline in VO_2max is not offset by individuals with higher levels of physical activity. Higher habitual levels of physical activity are accompanied by a higher VO_2max level at any age, and this advantage is maintained with ageing, but the accelerated rate of decline is similar to that of less habitually active individuals.

4.2.9 Jackson et al. (2009) reported data obtained on 16,889 men and 3,429 women who participated in the Dallas Aerobics Center Longitudinal Study from 1974 to 2006, with a median follow up period of six years. Complex statistical modelling confirmed an accelerated decline in cardiorespiratory fitness levels with ageing, and allowed the influence of common lifestyle variables (smoking, physical activity levels and body mass index) on this decline to be quantified. Figure 4.3 shows the accelerated decline in aerobic fitness levels with ageing in this US population.

Although the rate of decline in aerobic fitness appears greater in men as they age (Figure 4.3), when this decline is expressed relative to peak VO_2max or as the change in VO_2max from a young age (20-25 years), the difference between men and women disappears (Jackson et al., 2009).

4.2.10 Hence, the rate of decline in aerobic fitness levels with ageing is similar for men and women with similar initial VO_2max levels. This is evident from Figure 4.4, which shows the calculated change in VO_2max from 25 years of age, when physical activity levels and BMI remain constant (these are controlled for using the statistical modelling procedures). Taken together, the longitudinal studies by Fleg et al. (2005) and Jackson et al. (2009) provide powerful evidence that, in a healthy group of predominantly white, well educated individuals:

1. The age related decline in VO_2max is not linear, but accelerates with increasing age, especially after 45 years of age

2. When smoking status, physical activity levels and body mass index remain constant, VO_2max levels remain relatively stable until 40-50 years of age

3. The accelerated age related decline in VO_2max is not directly attenuated by high levels of physical activity, maintaining a normal body mass index or not smoking, but adhering to these lifestyle choices are accompanied by a higher VO_2max level at any age, and this advantage is maintained with ageing (see Figure 4.5)

4. Individuals who change their physical activity levels, body mass index or smoking status as they age will indirectly attenuate or accelerate their change in cardiorespiratory fitness levels, depending on the nature of these changes

5. The predicted changes in VO_2max accompanying these lifestyle choices for smoking status, physical activity levels and body mass index are shown in Table 4.2. Increasing physical activity levels, reducing BMI and quitting smoking will all increase VO_2max (NATO, 2009). Changes in these lifestyle variables in the opposite directions will decrease VO_2max

6. When natural population changes in smoking status, physical activity levels and body mass index with ageing were allowed (Figure 4.3), VO_2max declined from 50–55 years and 55–60 years by 1.4 and 1.7 $mL \cdot kg^{-1} \cdot min^{-1}$ respectively in men, and 1.2 and 1.5 $mL \cdot kg^{-1} \cdot min^{-1}$ respectively in women

7. When smoking status, physical activity levels and body mass index with ageing were held constant (Figure 4.4), VO_2max declined from 50–55 years and 55–60 years by 1.2 and 1.6 $mL \cdot kg^{-1} \cdot min^{-1}$ in men, and 1.0 and 1.2 $mL \cdot kg^{-1} \cdot min^{-1}$ respectively in women.

Figure 4.3 Age related changes in cardiorespiratory fitness in men and women from the Aerobics Center Longitudinal Study (Jackson et al., 2009), allowing for natural population change in smoking status, physical activity levels and body mass index with ageing

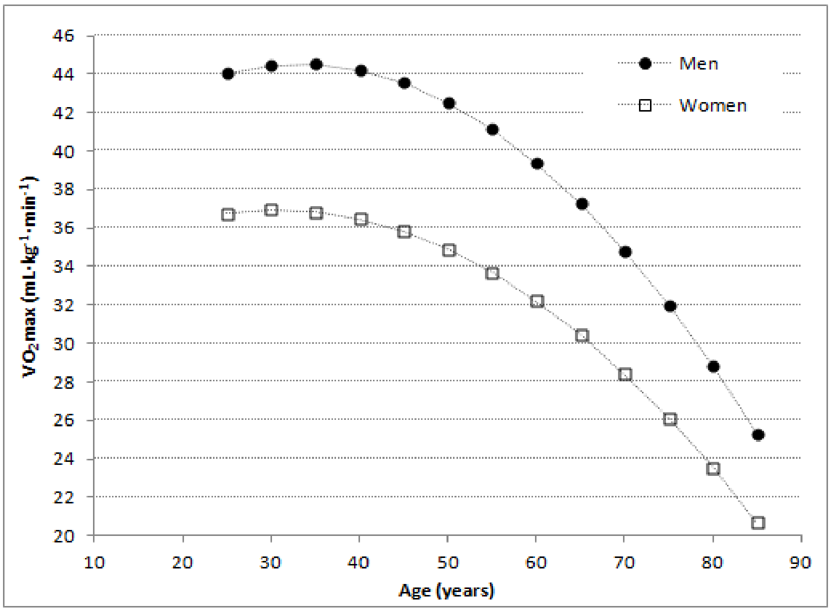


Figure 4.4 Age related changes in cardiorespiratory fitness from 25 years old in men and women from the Aerobics Center Longitudinal Study (Jackson et al., 2009), assuming smoking status, physical activity levels and body mass index do not change

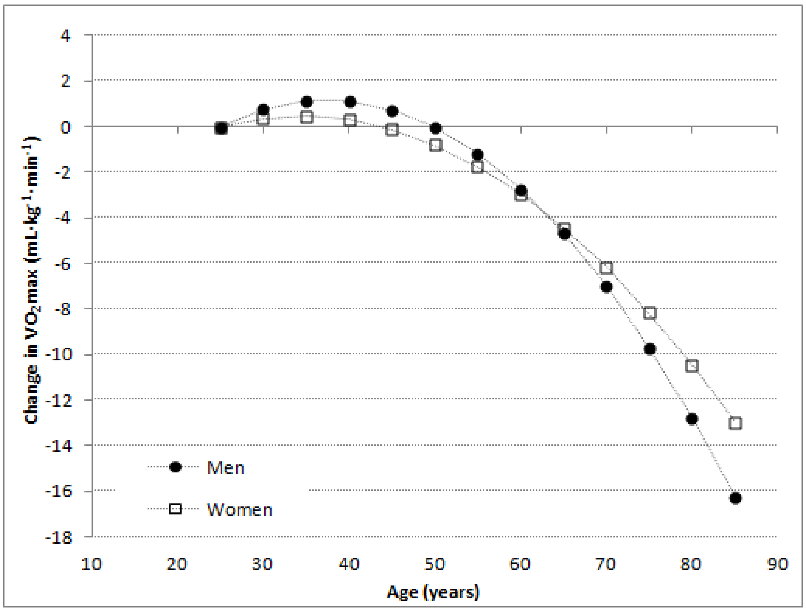


Figure 4.5 Theoretical changes in cardiorespiratory fitness levels for non-smoking men who maintain a different BMI (20 or 30 kg·m^{-2}) and physical activity levels (sedentary or moderately active – see Table 4.2 for definition) as they age (Jackson et al., 2009).

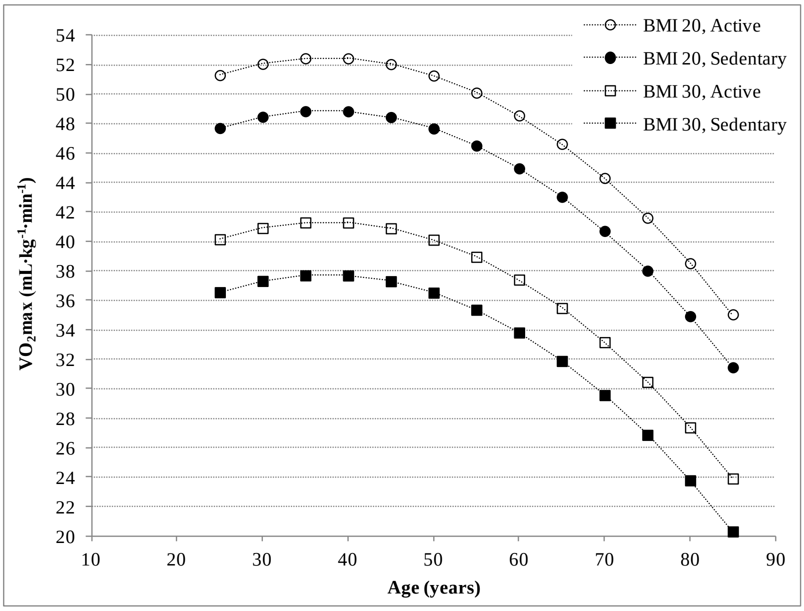


Table 4.2 Predicted change in VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$) accompanying changes in smoking status, physical activity levels and body mass index (Jackson et al., 2009). Note that changing lifestyle variables in the opposite direction will increase VO_2max by the same positive value shown below (e.g. stopping smoking for men will increase VO_2max by 1.4 $mL \cdot kg^{-1} \cdot min^{-1}$)

	Change in VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$)	
Lifestyle change	**Men**	**Women**
Start Smoking	-1.4	-1.0
A unit increase in BMI ($kg \cdot m^{-2}$)	-1.1	-0.7
High PAL to Sedentary PAL	-5.2	-4.3
Moderate PAL to Sedentary PAL	-3.6	-2.7
Low PAL to Sedentary PAL	-1.8	-1.3
Active PAL to Sedentary PAL	-1.3	-1.0

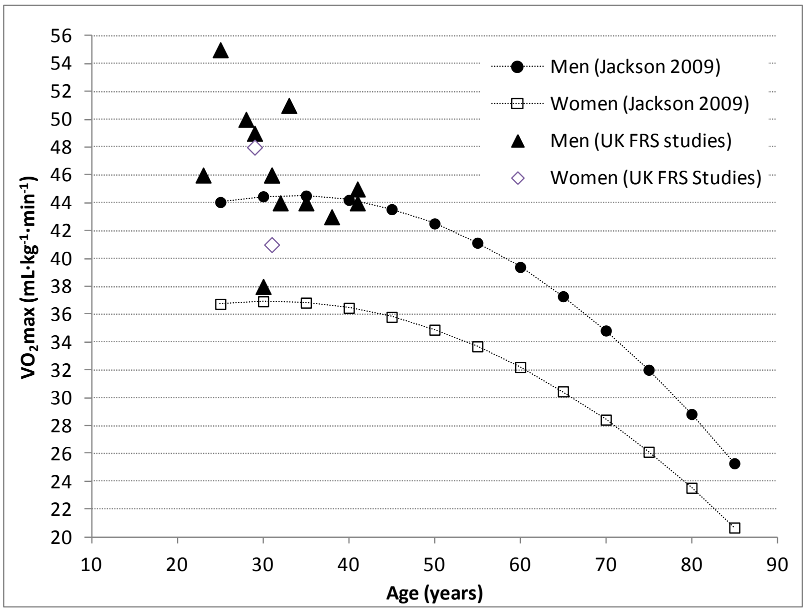
PAL physical activity level: Sedentary is no regular physical activity; Active is regular physical activity such as cycling, swimming, racquet sports, other strenuous sports, but not regular walking or jogging; Low is regular exercise - walked or jogged <10 miles per week, Moderate is regular exercise - walked or jogged 10–20 miles per week; High is regular exercise - walked or jogged >20 miles per week. Assuming a walking pace of 3.3 $miles \cdot h^{-1}$, Moderate PAL equates to a level of aerobic exercise of 180 min or more per week. This level of activity is slightly higher than the UK and US recommendations of ≥150 $min.week^{-1}$ of moderate intensity aerobic exercise required to developing and/or maintaining cardiorespiratory fitness (Garber et al., 2011, Haskell et al., 2007, O'Donovan et al., 2010).

4.3 Cardiorespiratory fitness levels in the Fire and Rescue Service

4.3.1 It is difficult to ascertain the current cardiorespiratory fitness status of the Fire and Rescue Service in England as there is no statutory requirement on Services to carry out periodic physical fitness assessments that measure or estimate VO_2max. Those Services that do require a periodic assessment of physical fitness use a variety of different tests. The most common include direct determination of VO_2max on a maximal treadmill test, estimation of VO_2max from maximal 20 m shuttle run performance or estimation of VO_2max from heart rate obtained on a sub-maximal step or treadmill test. In addition, some tests report a quantitative value for VO_2max, where others simply assess an individual has met a required minimum standard for VO_2max on a pass or fail basis, making the quantitative determination of VO_2max impossible. Finally fitness data held by Services are not centrally collated, and so hence are not readily accessible to investigation.

4.3.2 Table 4.3 shows the studies that have reported VO_2max for UK Fire and Rescue Service personnel. Although these studies report mean values on very small groups of firefighters (n=9–506) in comparison to the UK population of firefighters (> 40,000), the mean values for men are not dissimilar from those reported by Jackson et al. (2009) in the large Aerobics Center Longitudinal study, especially after acknowledging that participants in exercise and health related studies are usually in better physical condition than their peer population (see Figure 4.6). In support, previous studies have also suggested that UK firefighters do not appear to be dissimilar in fitness levels to the general population (Plat et al., 2012, Scott, 1988, Munir et al., 2012, Graveling, 2011a, Love et al., 1996).

Figure 4.6 Average VO_2max for UK Fire and Rescue Service (FRS) personnel with ageing (see Table 4.3) in comparison to an average ageing population (from Jackson et al., 2009)



4.3.3 The limited data on women would suggest that a woman firefighters' level of cardiorespiratory fitness is much higher than that of their peer population (Figure 4.6). This is expected, as the suggested minimum VO_2max requirement for operational duty for firefighters in the UK is 42 mL·kg^{-1}·min^{-1} (Stevenson et al., 2009), well above typical values for young women of 36-38 mL·kg^{-1}·min^{-1} (Figure 4.6). For reference, Table 4.4 shows cumulative percentile values for VO_2max in a large population for men (n=44,082) and women (n=14,769) of differing age, based on the Aerobics Center Longitudinal study data (Thompson et al., 2010).

4.3.4 Figures 4.3 and 4.6 show that after approximately 45 years of age, the rate of decline in relative VO_2max is greater for men than women (Fleg et al., 2005, Jackson et al., 2009). However, as discussed above, this appears to be a function of the men's higher mean VO_2max, as gender differences disappear when the decline is expressed as a percentage of peak VO_2max (Jackson et al., 2009). Therefore, men and women with the same initial VO_2max will experience a very similar age related decline in VO_2max if changes in lifestyle factors are similar (Jackson et al., 2009). Despite this fact, it is important to note that a much lower proportion of women will be able to achieve any threshold VO_2max level in comparison to men. For example,

~60 % of young men will have a VO_2max level of ≥42 $mL \cdot kg^{-1} \cdot min^{-1}$ in comparison to ~25 % of young women (see Table 4.4).

Table 4.3 Summary of studies reporting VO_2max in UK Fire and Rescue Service Firefighters

Study	Number (Men; Women)	FRS	Age ± SD/ range (years)	VO_2max ± SD/ range ($mL{\cdot}kg^{-1}{\cdot}min^{-1}$)	VO_2max Protocol
Brown et al., (1982)	30		30	38	
Scott (1988)	278	London, Greater Manchester, West Yorkshire, Devon, Kent and South Glamorgan	32	44 ± 8	Maximal Cycle
Ellam et al., (1994)[a]	40		23 / 18-30	46 ± 7	
Love et al., (1996)	FT: 68 M; 4 W (n=72)	12 UK FRSs	31/ 21-48	46	Submaximal treadmill
David et al., (1997)	30		25 ± 3	55 ± 6	Maximal shuttle or cycle
Brewer et al., (1999)[c]	M 128; W 10 (n=138)	London FRS		M 48 W 44	Maximal Shuttle Run
Hooper et al., (2001)	FT: 21 M; 1 W (n=22)	West Midlands FRS	35 ± 8 / 21-54	44 ± 6 / 34-58	Submaximal Step
Eglin et al., (2004)	14 FT Instructors (14 M)	Fire Service College	38 ± 3	43 ± 8	Submaximal Step
Carter et al., (2007)	FT: 10 M	Mixed FRS	33 ± 4	51 ± 7	Maximal Treadmill
Barr et al., (2008)	12 M	Merseyside FRS	41 ± 8 / 28-50	44 ± 4	Maximal Treadmill
Barr et al., (2009)	FT: 9 M	Merseyside FRS	41 ± 7 / 28-52	45 ± 5	Maximal Treadmill
Rayson et al., (2009a)	80 M; 17 W (n=97)	London, Somerset, Manchester and West Yorkshire FRSs	M 29 ± 7 W 31 ± 6	M 49 ± 5 W 41 ± 7	Maximal Shuttle Run
Wynn et al., (2012)	FT: ~383 M; 28 W (n=411) PT:~ 89 M; 6 W (n=95)	Tyne and Wear FRS and Durham and Darlington FRS	28 ± 6/ 18-47 29 ± 8/ 17-51	50 ± 7 / 32-89 48 ± 8 / 32-70	Submaximal Step

M is Men, W is Women, FRS is Fire and Rescue Service, FT is full time (whole time), PT is part time (retained)

[c] Cited in RAYSON, M. P., DONOVAN, K., GRAVELING, R. A. & JONES, D. A. 2004a. Operational physiological capabilities of firefighters: Literature review and research recommendations. London, UK: Optimal Performance Limited on behalf of the Office for the Deputy Prime Minister.

Table 4.4 Population percentile values for cardiorespiratory fitness levels (VO_2max in mL·kg^{-1}·min^{-1}) with ageing (Thompson et al., 2010)

	Men VO_2max (mL·kg^{-1}·min^{-1})						**Women VO_2max (mL·kg^{-1}·min^{-1})**				
	Age (Years)						**Age (Years)**				
%	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**		**20-29**	**30-39**	**40-49**	**50-59**	**60-69**
99	61.2	58.3	57.0	54.3	51.1		55.0	52.5	51.1	45.3	42.4
95	56.2	54.3	52.9	49.7	46.1		50.2	46.9	45.2	39.9	36.9
90	54.0	52.5	51.1	46.8	43.2		47.5	44.7	42.4	38.1	34.6
85	52.5	50.7	48.5	44.6	41.0		45.3	42.5	40.0	36.7	33.0
80	51.1	48.9	46.8	43.3	39.5		44.0	41.0	38.9	35.2	32.3
75	49.2	47.5	45.4	41.8	38.1		43.4	40.3	38.1	34.1	31.0
70	48.2	46.8	44.2	41.0	36.7		41.1	38.8	36.7	32.9	30.2
65	46.8	45.3	43.9	39.5	35.9		40.6	38.1	35.6	32.3	29.4
60	45.7	44.4	42.4	38.3	35.0		39.5	36.7	35.1	31.4	29.1
55	45.3	43.9	41.0	38.1	33.9		38.1	36.7	33.8	30.9	28.3
50	43.9	42.4	40.4	36.7	33.1		37.4	35.2	33.3	30.2	27.5
45	43.1	41.4	39.5	36.6	32.3		36.7	34.5	32.3	29.4	26.9
40	42.2	41.0	38.4	35.2	31.4		35.5	33.8	31.6	28.7	26.6
35	41.0	39.5	37.6	33.9	30.6		34.6	32.4	30.9	28.0	25.4
30	40.3	38.5	36.7	33.2	29.4		33.8	32.3	29.7	27.3	24.9
25	39.5	37.6	35.7	32.3	28.7		32.4	30.9	29.4	26.6	24.2
20	38.1	36.7	34.6	31.1	27.4		31.6	29.9	28.0	25.5	23.7
15	36.7	35.2	33.4	29.8	25.9		30.5	28.9	26.7	24.6	22.8
10	35.2	33.8	31.8	28.4	24.1		29.4	27.4	25.6	23.7	21.7
5	32.3	31.1	29.4	25.8	22.1		26.4	25.5	24.1	21.9	20.1
1	26.6	26.6	25.1	21.3	18.6		22.6	22.7	20.8	19.3	18.1
n	2606	13158	16534	9102	2682		1350	4394	4834	3103	1088

n= number of individuals in each age category

4.4 Modelling the effects of ageing on the number of Fire and Rescue Service personnel fit for duty

4.4.1 If the cardiorespiratory fitness levels of the UK Fire and Rescue Service are similar to the UK healthy population, and assuming our best approximation of this healthy population and the effects of lifestyle choices and ageing on these fitness levels are similar to those reported for the large US population reported by Jackson et al. (2009), it is possible to estimate the number of firefighters who would meet cardiorespiratory standards to be fit for duty as they age. However, as discussed in Section 2.3, the cardiorespiratory standard for the UK Fire and Rescue Service is not clearly defined, nor is it easily definable. In the absence of an accepted cardiorespiratory standard required by firefighters, the standard adopted by FireFit of above 42 $mL \cdot kg^{-1} \cdot min^{-1}$ will be used as reference value for ‘safe’ operational duty (Stevenson et al., 2009).

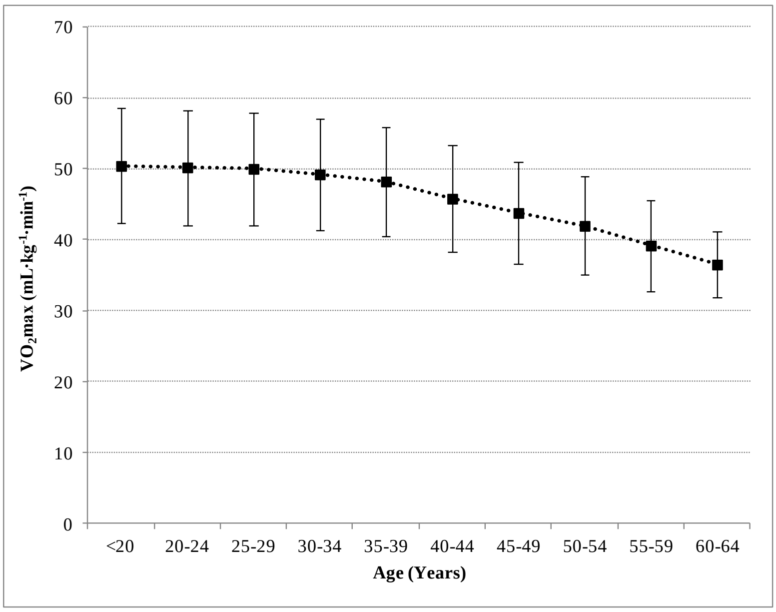
4.4.2 These calculations assume firefighters are drawn from a normal healthy population, which has a mean VO_2max similar to a healthy population of ~44 $mL \cdot kg^{-1} \cdot min^{-1}$ (Scott, 1988, Jackson et al., 2009, Thompson et al., 2010), and the decline with ageing follows the changes shown in Figure 4.2 (Shvartz and Reibold, 1990) and Figure 4.4 (Jackson et al., 2009). Assuming cardiorespiratory fitness levels are normally distributed around this mean, a standard deviation of 7 $mL \cdot kg^{-1} \cdot min^{-1}$ seems a reasonable estimate based on the larger sample estimates for firefighters reported in Table 4.3 (Rayson et al., 2009a, Scott, 1988, Wynn and Hawdon, 2012). Data provided by the American College of Sports Medicine suggest that this standard deviation remains fairly constant in a healthy population from 20-60 years of age (Thompson et al., 2010).

4.4.3 In the best case scenario, where firefighters maintain their physical activity status, body mass index and smoking status as they age, the distribution of VO_2max and estimated cumulative percentage of firefighters who would be fit for operational duty (above 42 $mL \cdot kg^{-1} \cdot min^{-1}$) can be estimated (see Table 4.5). This table has been top-sliced at the 35th percentile to exclude all those individuals in the population who would not meet the minimum selection standard for a young (<25 years) firefighter (i.e. 42 $mL \cdot kg^{-1} \cdot min^{-1}$). The 65th percentile distribution remaining after this top-slicing was then adjusted to represent the predicted distribution of firefighters. For example, the original 40th percentile would now correspond to the 5th percentile of the remaining 65th percentile i.e. 5/65 which is equivalent to ~ 8th percentile. From Table 4.5, at 55 years of age, approximately 15 % of firefighters would be below the minimum standard required for operational duty. By 60 years, this percentage would have increased to 23 %.

4.4.4 For a worst case scenario, where firefighters physical activity status, body mass index and smoking status follow the typical age related changes in the population, assuming a yearly decline of 0.42 $mL \cdot kg^{-1} \cdot min^{-1}$ per year (Shvartz and Reibold, 1990), the distribution of VO_2max and estimated cumulative percentage of firefighters who would be fit for operational duty (above 42 $mL \cdot kg^{-1} \cdot min^{-1}$) is shown in Table 4.6. From Table 4.6, at 55 years of age, approximately 85 % of firefighters would be below the minimum standard required for operational duty. By 60 years, this percentage would increase to 92 %.

4.4.5 Recent data collated as part of this review process on aerobic fitness for 7774 personnel from four UK Fire and Rescue Services (comprising 6725 whole-time and 1049 retained personnel, of which 7547 were men and 227 women representing a 78.4 % response rate) found the average VO_2max in this sub-population was 46 ± 8 $mL \cdot kg^{-1} \cdot min^{-1}$. Figure 4.7 shows the change in VO_2max with ageing for this group. Of note is that for young personnel (≤30 years), the average VO_2max is ~ 50 $mL \cdot kg^{-1} \cdot min^{-1}$, and that VO_2max does not start to decline until 35–45 years of age. At 50-54 years of age 51 % (n=417/822) of firefighters were below 42 $mL \cdot kg^{-1} \cdot min^{-1}$. At 55-60 years 66 % (n=70/106) of firefighters were below this standard.

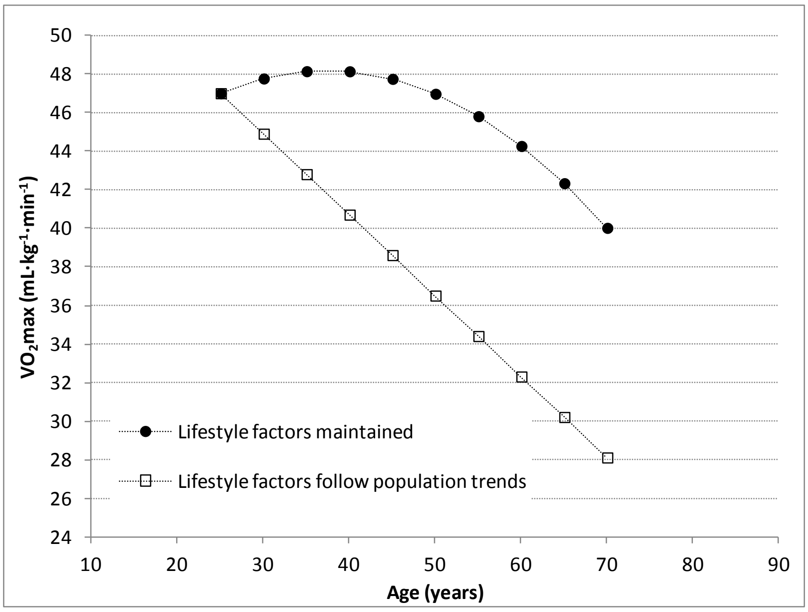
Figure 4.7 Mean (±SD) VO_2max from four UK Fire and Rescue Services with age. Data were from 7774 personnel comprising 6725 wholetime and 1049 retained personnel, of which 7547 were men and 227 women, representing a 78.4 % response rate.



4.4.6 The top-slicing approach to describing the distribution of cardiorespiratory fitness levels for young firefighters would equate to a mean VO_2max for young firefighters of approximately 47 $mL \cdot kg^{-1} \cdot min^{-1}$ (see Tables 4.5 and 4.6). This is very similar to the data obtained from the four UK Fire and Rescue Services (see 4.4.5 and Figure 4.7), especially when accepting this data only represents a 78.4 % response rate.

4.4.7 Figure 4.8 shows a graphical representation of the average (50th percentile of the firefighter population) predicted decline in VO_2max for these two theoretical conditions for lifestyle change with ageing (Shvartz and Reibold, 1990, Jackson et al., 2009), assuming a starting VO_2max of 47 $mL \cdot kg^{-1} \cdot min^{-1}$.

Figure 4.8 Average VO_2max for UK Fire and Rescue Service (FRS) personnel with ageing, assuming lifestyle factors are maintained (Jackson et al., 2009) or follow the typical population decline (Shvartz and Reibold, 1990), assuming a starting VO_2max of 47 $mL·kg^{-1}·min^{-1}$.



4.4.8 In the absence of definitive data on the VO_2max required to effectively perform firefighting roles, and the lack of data describing the current cardiorespiratory fitness levels of the Fire and Rescue Service in England, the best available evidence reviewed in this report suggests that increasing the normal pension age would increase the percentage of firefighters unable to meet the proposed recommend standard of 42 $mL·kg^{-1}·min^{-1}$ (Stevenson et al., 2009) from between 15–85 % at 55 years to 23–92 % at 60 years. The lower estimates of a 15 to 23 % change from 55 to 60 years assume physical activity levels, body mass index and smoking status are maintained with ageing. The higher estimated of 85-92 % from 55 to 60 years assume a normal population change in these lifestyle factors with ageing. These latter values are very similar to those reported by Graveling et al., (2011a), reporting a 92-95 % change from 55 to 60 years, based on data assuming a normal population change in these lifestyle factors with ageing.

4.4.9 The impact of a different initial VO_2max on the number of personnel fit for duty as they age can easily be calculated by adjusting the data presented in Tables 4.5 and 4.6 by the difference between the required starting VO_2max and 44 $mL·kg^{-1}·min^{-1}$ (the initial VO_2max value used to calculate Tables 4.5 and 4.6). For example, to assess the impact of changing the initial VO_2max to 50 $mL·kg^{-1}·min^{-1}$, simply add 50 - 44 = 6 $mL·kg^{-1}·min^{-1}$ to all values in Tables 4.5 and 4.6, and evaluate the percentage of the population who can achieve the desired VO_2max standard (e.g. 42 $mL·kg^{-1}·min^{-1}$ for firefighters).

4.4.10 For Fire and Rescue Service personnel in predominantly management roles who have a genuine occupational requirement to wear BA at incidents, a minimum aerobic fitness level of approximately 25 $mL·kg^{-1}·min^{-1}$ has been proposed (see

Section 2.3). Table 4.5 shows all healthy firefighters should be able to achieve this cardiorespiratory standard at 60 years of age, assuming they start with an initial VO_2max of at least 42 $mL \cdot kg^{-1} \cdot min^{-1}$. This assumes they can maintain their physical activity levels and BMI as they age.

4.4.11 Table 4.6 shows that this would also be the case for all healthy firefighters who start with an initial VO_2max of at least 42 $mL \cdot kg^{-1} \cdot min^{-1}$ and allow their levels of physical activity and BMI to follow the typical UK population changes with ageing.

4.4.12 The minimum quantity and quality of exercise required to develop and maintain cardiorespiratory, musculoskeletal, neuromotor fitness and health has been well documented (Haskell et al., 2007, Garber et al., 2011, O'Donovan et al., 2010). Specific advice for firefighters looking to develop or maintain their physical fitness is available from FireFit (Stevenson et al., 2007).

4.5 Summary

4.5.1 Cardiorespiratory fitness levels (VO_2max) decline with age. The extent of this decline is heavily influenced by lifestyle choices that impact on BMI, physical activity levels and smoking status.

4.5.2 If lifestyle choices remain unchanged, VO_2max will remain stable until ~ 40-45 years of age before following an accelerated decline with ageing.

4.5.3 Modifying lifestyle choices can increase, maintain or decrease cardiorespiratory fitness levels with ageing, depending upon the direction and magnitude of these changes.

4.5.4 For the same initial VO_2max level and lifestyle choices, the rate of decline in cardiorespiratory fitness levels will not be different for men and women as they age.

4.5.5 It is possible to estimate the number of Fire and Rescue Service personnel who will become unfit for duty with ageing due to low levels of cardiorespiratory fitness. However, these estimates require a number of assumptions to be made.

4.5.6 This review is not endorsing any aerobic fitness standards, and acknowledges the limitations of just using a discrete physiological measure (e.g. VO_2max) to quantify overall firefighting physical performance ability.

4.5.7 However, to demonstrate an example, assume young firefighters had an average VO_2max of 47 $mL \cdot kg^{-1} \cdot min^{-1}$ and maintained their BMI and physical activity levels as they age. Assuming safe and effective firefighting performance required a minimum VO_2max of 42 $mL \cdot kg^{-1} \cdot min^{-1}$, the age related decline in VO_2max would indicate that 15 % of firefighters would be unfit for duty at 55 years, increasing to 23 % at 60 years of age (see Table 4.5).

4.5.8 These percentages would increase to 85 % and 92 % respectively if firefighters followed the normal population patterns for increasing BMI and decreasing physical activity levels with ageing (see Table 4.6).

4.5.9 For Fire and Rescue Service personnel in predominantly management roles, assuming safe and effective performance required a minimum VO_2max of 25 $mL \cdot kg^{-1} \cdot min^{-1}$, the age related decline in VO_2max would indicate that essentially all healthy management personnel would be able to meet this standard at 60 years, irrespective of which of the two lifestyle choices they followed with ageing (see Table 4.5 and 4.6).

4.5.10 The absolute number of firefighter and management personnel fit for duty at any time will depend, in part, on their initial cardiorespiratory fitness levels at entry to the service, the lifestyle choices they follow during service, and the minimum physical standards required for safe and effective performance in these roles.

4.5.11 Accepting the assumptions required to undertake this analysis, changing the retirement age from 55 to 60 years is estimated to create an additional 8 % of firefighters and 0 % of management personnel unable to meet the cardiorespiratory fitness standards required by their role.

Table 4.5 Estimated cumulative percentage of firefighters who would be below the minimum VO_2max standard recommended for operational duty (i.e. 42 $mL \cdot kg^{-1} \cdot min^{-1}$ shown in RED) and above the minimum recommended standard for operational duty (shown in GREEN), based on the age related decline in VO_2max reported by Jackson et al., (2009). This Table assumes physical activity levels, body mass index and smoking status were maintained with ageing from a population average initial VO_2max of 44 ± 7 $mL \cdot kg^{-1} \cdot min^{-1}$, and that the Table was top-sliced at the 35th percentile for firefighters to exclude individuals who would not meet the minimum entry standard at 25 years of age (see 4.4.3).

		Cardiorespiratory Fitness Level (VO_2max in $mL \cdot kg^{-1} \cdot min^{-1}$)									
Population Cumulative Percentage	**Firefighter Cumulative Percentage**	**Age (Years)**									
		25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**
1	These individuals would not have been selected at 25 years as they do not meet the required standard of 42 $mL \cdot kg^{-1} \cdot min^{-1}$	27.7	28.5	28.9	28.9	28.5	27.7	26.5	25.0	23.1	20.7
5		32.5	33.3	33.6	33.6	33.2	32.5	31.3	29.8	27.8	25.5
10		35.0	35.8	36.2	36.2	35.8	35.0	33.9	32.3	30.4	28.1
15		36.8	37.5	37.9	37.9	37.5	36.7	35.6	34.0	32.1	29.8
20		38.1	38.9	39.3	39.3	38.9	38.1	36.9	35.4	33.5	31.1
25		39.3	40.1	40.4	40.4	40.0	39.3	38.1	36.6	34.6	32.3
30		40.3	41.1	41.5	41.5	41.1	40.3	39.2	37.6	35.7	33.4
35		41.3	42.1	42.5	42.5	42.1	41.3	40.1	38.6	36.6	34.3
		Table top-sliced at 35th percentile for firefighters (see 4.4.3)									
40	**8**	**42.2**	**43.0**	**43.4**	**43.4**	**43.0**	**42.2**	**41.0**	**39.5**	**37.6**	**35.3**
45	**15**	**43.1**	**43.9**	**44.3**	**44.3**	**43.9**	**43.1**	**41.9**	**40.4**	**38.5**	**36.1**
50	**23**	**44.0**	**44.8**	**45.2**	**45.2**	**44.8**	**44.0**	**42.8**	**41.3**	**39.3**	**37.0**
55	**31**	**44.9**	**45.7**	**46.0**	**46.0**	**45.6**	**44.9**	**43.7**	**42.2**	**40.2**	**37.9**
60	**38**	**45.8**	**46.6**	**46.9**	**46.9**	**46.5**	**45.8**	**44.6**	**43.0**	**41.1**	**38.8**
65	**46**	**46.7**	**47.5**	**47.9**	**47.8**	**47.5**	**46.7**	**45.5**	**44.0**	**42.0**	**39.7**
70	**54**	**47.7**	**48.4**	**48.8**	**48.8**	**48.4**	**47.7**	**46.5**	**44.9**	**43.0**	**40.7**
75	**62**	**48.7**	**49.5**	**49.9**	**49.9**	**49.5**	**48.7**	**47.5**	**46.0**	**44.1**	**41.7**
80	**69**	**49.9**	**50.7**	**51.0**	**51.0**	**50.7**	**49.9**	**48.7**	**47.2**	**45.2**	**42.9**
85	**77**	**51.3**	**52.0**	**52.4**	**52.4**	**52.0**	**51.2**	**50.1**	**48.5**	**46.6**	**44.3**
90	**85**	**53.0**	**53.7**	**54.1**	**54.1**	**53.7**	**53.0**	**51.8**	**50.2**	**48.3**	**46.0**
95	**92**	**55.5**	**56.3**	**56.7**	**56.7**	**56.3**	**55.5**	**54.3**	**52.8**	**50.9**	**48.5**
99	**98**	**60.3**	**61.1**	**61.4**	**61.4**	**61.0**	**60.3**	**59.1**	**57.6**	**55.6**	**53.3**

Table 4.6 Estimated cumulative percentage of firefighters who would be below the minimum VO_2max standard recommended for operational duty (i.e. 42 mL·kg^{-1}·min^{-1} shown in RED) and above the minimum recommended standard for operational duty (shown in GREEN), based on the age related decline in VO_2max reported by (Shvartz and Reibold, 1990). This Table assumes typical population changes physical activity levels, body mass index and smoking status with ageing from a population average initial VO_2max of 44 ± 7 mL·kg^{-1}·min^{-1}, and that the Table was top-sliced at the 35th percentile for firefighters to exclude individuals who would not meet the minimum entry standard at 25 years of age (see 4.4.3).

		Cardiorespiratory Fitness Level (VO_2max in mL·kg^{-1}·min^{-1})									
Population Cumulative Percentage	**Firefighter Cumulative Percentage**	**Age (Years)**									
		25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**
1	These individuals would not have been selected at 25 years as they do not meet the required standard of 42 mL·kg^{-1}·min^{-1}	27.7	25.6	23.5	21.4	19.3	17.2	15.1	13.0	10.9	8.8
5		32.5	30.4	28.3	26.2	24.1	22.0	19.9	17.8	15.7	13.6
10		35.0	32.9	30.8	28.7	26.6	24.5	22.4	20.3	18.2	16.1
15		36.8	34.7	32.6	30.5	28.4	26.3	24.2	22.1	20.0	17.9
20		38.1	36.0	33.9	31.8	29.7	27.6	25.5	23.4	21.3	19.2
25		39.3	37.2	35.1	33.0	30.9	28.8	26.7	24.6	22.5	20.4
30		40.3	38.2	36.1	34.0	31.9	29.8	27.7	25.6	23.5	21.4
35		41.3	39.2	37.1	35.0	32.9	30.8	28.7	26.6	24.5	22.4
		Table top-sliced at 35th percentile for firefighters (see 4.4.3)									
40	**8**	**42.2**	**40.1**	**38.0**	**35.9**	**33.8**	**31.7**	**29.6**	**27.5**	**25.4**	**23.3**
45	**15**	**43.1**	**41.0**	**38.9**	**36.8**	**34.7**	**32.6**	**30.5**	**28.4**	**26.3**	**24.2**
50	**23**	**44.0**	**41.9**	**39.8**	**37.7**	**35.6**	**33.5**	**31.4**	**29.3**	**27.2**	**25.1**
55	**31**	**44.9**	**42.8**	**40.7**	**38.6**	**36.5**	**34.4**	**32.3**	**30.2**	**28.1**	**26.0**
60	**38**	**45.8**	**43.7**	**41.6**	**39.5**	**37.4**	**35.3**	**33.2**	**31.1**	**29.0**	**26.9**
65	**46**	**46.7**	**44.6**	**42.5**	**40.4**	**38.3**	**36.2**	**34.1**	**32.0**	**29.9**	**27.8**
70	**54**	**47.7**	**45.6**	**43.5**	**41.4**	**39.3**	**37.2**	**35.1**	**33.0**	**30.9**	**28.8**
75	**62**	**48.7**	**46.6**	**44.5**	**42.4**	**40.3**	**38.2**	**36.1**	**34.0**	**31.9**	**29.8**
80	**69**	**49.9**	**47.8**	**45.7**	**43.6**	**41.5**	**39.4**	**37.3**	**35.2**	**33.1**	**31.0**
85	**77**	**51.3**	**49.2**	**47.1**	**45.0**	**42.9**	**40.8**	**38.7**	**36.6**	**34.5**	**32.4**
90	**85**	**53.0**	**50.9**	**48.8**	**46.7**	**44.6**	**42.5**	**40.4**	**38.3**	**36.2**	**34.1**
95	**92**	**55.5**	**53.4**	**51.3**	**49.2**	**47.1**	**45.0**	**42.9**	**40.8**	**38.7**	**36.6**
99	**98**	**60.3**	**58.2**	**56.1**	**54.0**	**51.9**	**49.8**	**47.7**	**45.6**	**43.5**	**41.4**

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5 Muscular Strength and Endurance

Victoria L. Richmond, David M. Wilkinson and Mark P. Rayson

5.1 Literature Search

5.1.1 Several key tasks have been identified in the job analysis for firefighting (Chapter 2), and muscular strength and endurance are major determinants of performance on these tasks (Rayson et al., 2004b, Henderson et al., 2007a). Strength can be defined as "the maximal force a muscle or muscle group can generate at a specified velocity" (Knuttgen and Kraemer, 1987). Muscular endurance is "the time limit of a person's ability to maintain a force or power level" (Knuttgen and Kraemer, 1987) and is closely associated with aerobic fitness, especially as task duration increases. It is hard to separate these two physical requirements in the firefighting role, as performance on many tasks will be determined by muscular strength, muscular endurance and aerobic fitness (Henderson et al., 2007a, Rayson et al., 2009c).

5.1.2 Load carriage is a fundamental requirement for a firefighter, with the standard duration breathing apparatus and turnout firefighting personal protective clothing (PPE) weighing ~24 kg, increasing to ~33 kg with extended duration breathing apparatus (EDBA) (Richmond et al., 2008). In Chemical, Biological, Radiological and Nuclear (CBRN) conditions firefighters wear the Gas Tight Suit with EDBA, which have a total weight of ~34 kg (Rayson et al., 2005b). Muscular endurance is a clear determinant for the ability to wear protective clothing for extended periods, especially when carrying out tasks such as stair climbing and carrying hose. There are firefighting tasks which require muscular strength alone, such as lifting a 13.5 m ladder on to the appliance (Rayson et al., 2009d). However, most tasks include an element of pure strength in combination with muscular and aerobic endurance, such as lifting a casualty prior to dragging or carrying, lifting and carrying a portable pump (33 kg) or lifting and carrying coiled hose (15 kg) (see Table 2.4 in Chapter 2).

5.1.3 Old age is associated with inevitable time-dependent losses in physical capability (Bassey, 1998), and this includes muscular strength and endurance. Chapter 3 notes that sarcopenia occurs from the age of about 55 years (Booth et al., 1994), which will result in a loss of muscular strength. However, loss in strength in older adults is much more than the concomitant loss of muscle mass, indicating that maintaining or even increasing muscle mass with age does not necessarily prevent the decline in strength (Goodpaster et al., 2006). While it may not be possible to prevent the decline in muscle quality with age, the decline in strength can be attenuated by exercise (Cooper et al., 2011) and maintaining appropriate strength training (Mazzeo et al., 1998). A report by Rayson et al. (2009d) provides guidelines on physical preparation to undertake the National Firefighter selection Test (NSFT), including strength training exercises. This sort of exercise could help attenuate the decline in lean muscle mass with ageing. To assess the impact of age on changes in muscular strength and endurance with ageing, a literature search was carried out to identify the key papers and reports in this area.

5.1.4 To address the question, “how does muscular strength and endurance change with age”, MEDLINE, was searched using PubMed (as described in Chapter 3). The search terms ‘aging AND exercise AND strength’ returned 61 results in the clinical study categories. Studies were excluded if they did not include a quantifiable measure of muscular strength (e.g. hand grip) across the age ranges, did not include an age range spanning ≥18 but ≤ 45 years to ≥ 60 years, knowingly included individuals with chronic disease or mental illness, or did not have a gender specific sample size of at least 100 individuals. One study remained (Nolan et al., 2010). The search term ‘muscular endurance AND ageing’ returned four results in the clinical study category, all of which were excluded. Due to the lack of information found relating to muscular endurance, a systematic review search was carried out in PubMed. Five review papers were returned in the search, and one of these was selected to assess for further work on this area (Bemben, 1998) due to its relevance to the selection criteria.

5.1.5 Known key national sources of normative data on changes in muscular strength and endurance with ageing were reviewed: the Allied Dunbar National Fitness Survey (Allied Dunbar National Fitness Survey, 1992b) and the American College of Sports Medicine’s Guidelines for Exercise Testing and Prescription (Thompson et al., 2010). In addition, past reports relating to physical fitness and/or pension age in the Fire and Rescue Service were also reviewed (Rayson et al., 2004b, Rayson et al., 2009c, Rayson et al., 2009d, Haisman, 1996a, Graveling and Crawford, 2011b). All relevant references cited in the reviewed papers, books and reports identified were also investigated if they helped explain the change in muscular strength and endurance with age.

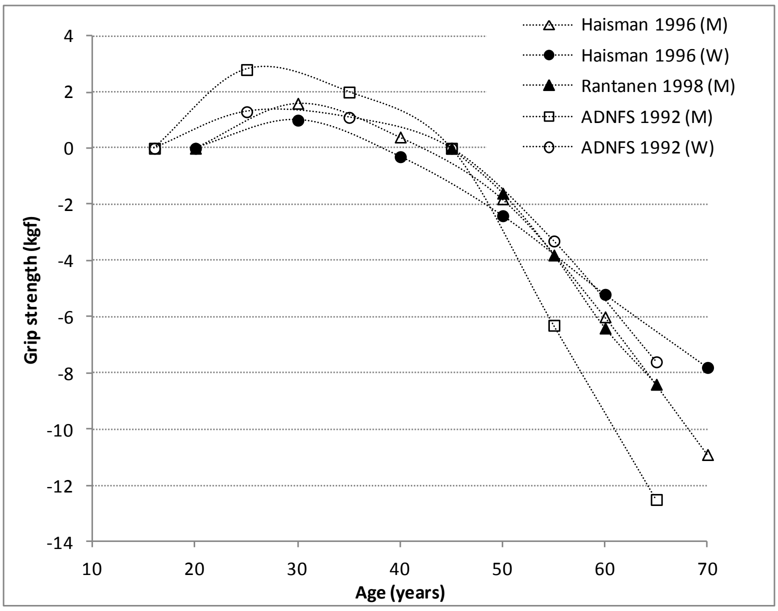
5.1.6 From the entire search, five reports were selected (main details of which are summarised in Table 5.2 and only details relevant to this review of literature have been included). A caveat must be included at this point to state that tests commonly used in a laboratory setting to assess strength are generally not very well correlated with fire-fighter task performance (Gleeson and Mercer, 1996) However, in the absence of any large cohort studies assessing the impact of age on measures of firefighter strength, the effect of ageing on strength in the general population will be discussed and related to the firefighter population. In addition, the papers that will be discussed concentrate on changes in muscular strength. Muscular endurance is hard to isolate as a stand-alone measure due to its close association with aerobic fitness, but is of importance to consider, especially when assessing the impact of age on recovery and redeployment.

5.1.7 Longitudinal studies provide the most reliable data on the effects of ageing on physiological parameters, as statistical procedures can control for changes in lifestyle factors which confound the influence of changes due to age alone. In the absence of well controlled longitudinal studies, cross sectional studies provide useful information, accepting the confounding issues related to lifestyle change. The Allied Dunbar National Fitness Survey (ADNFS) reported the decline in hand grip strength for a cross-sectional sample of men and women (age 16-74 years) from the UK population (1992b). Grip strength remained stable to the age of 45 years, after which there was a sudden increase in the rate at which strength declined, losing about 3 kgf between the ages of 50-55 years and between the ages of 55-60 years (Figure 5.1). The decline in strength for men and women was similar. However, at all ages women have only about 65 % of the strength of men (Shephard, 1999). Rantanen et al. (1998) followed 3700 men over 27 years as part of a longitudinal study to assess changes in grip strength. The percentage decline in strength per five years accelerated with increasing age (4.3 % for 45-49 yrs and 7.5 % for 65-68 yrs). Weight loss was a significant determinant of the rate of grip strength loss, being 5 to 6 times greater for individuals who had lost 5 kg body mass. Lean cross-sectional area of the arm was estimated from the upper arm circumference and tricep skinfold thickness, and was reported to decrease by ~7 cm^2 between the ages of 45 and 68 years. This suggests that a large proportion of the weight loss occurring with increasing age was due to a loss of lean mass (Going et al., 1995). The decline per year in grip strength reported by these studies, as well as data from a review paper by Haisman (1996a), are shown in Figure 5.1. All studies report a similar pattern of decline and reduction in strength, with grip strength maintained to the age of 40-45 years, followed by a progressively accelerated decline with ageing. Table 5.1 shows the average decline in grip strength for these studies. These data equate to an annual decline of 1 ± 0.2 % between the ages of 50 and 55 years, and 1.1 ± 0.3 % between the ages of 55 and 60 years. These values are within the range reported by Kenny (2008) in a review of the literature on the effects of ageing on strength parameters (between 0.8 % and 5 % decline per year).

Table 5.1 Average decline in grip strength from baseline (20-25 yrs) from Haisman et al. (1996a), Rantanen et al. (1998) and ADNFS (1992b)

Age	Decline in Force from 20-25 years (kgf)	Percentage Change in Force from 20-25 years (%)
45	-0.5 ± 0.6	1.3
50	-2.1 ± 0.7	5.4
55	-4.2 ± 1.2	10.3
60	-6.5 ± 1.7	17.2

Figure 5.1 Yearly decline in grip strength. Data taken from Allied Dunbar National Fitness Survey (1992b), Rantenan (1998) and Haisman (1996a).



5.1.8 Table 5.2 also includes studies which have reported declines in leg strength with ageing. It has not been possible to combine the data from these studies into a single figure due to differences in units of measurement. Additionally, two of the studies report leg strength relative to body mass and although those data do provide reliable information on the decline in strength with age, changes in body mass will result in changes in relative strength, but not necessarily absolute strength. Frontera et al. (1991) assessed the absolute strength of the elbow and knee, using an isokinetic dynamometer, on 200 men and women between the ages of 45 and 78 years. Absolute strength was ~20 % lower in the older age group (65-78 years) than the younger age group (45-55 years), although this difference was either completely eliminated or reduced when corrected for differences in muscle mass. Runge et al. (2004) used a standing jump to assess peak power in 258 men and women age 18-88 years. This study reported a linear relationship between age and jump power, with peak power dropping by 7 % every five years, despite no change in muscle cross section with age (an indicator of muscle mass). The reduction in strength was thought to be as a result of a combination of changes in muscle function and tendon properties, as well as changes in body composition. Nolan et al. (2010) measured leg strength using a spring gauge on 106 men between 30 and 80 years. Muscular strength of the quadriceps peaked in the 30's and was significantly reduced in the 50's (decreasing 7% over ten years) and furthermore in the 60s (decreasing 16% over ten years).

5.1.9 This review on the effects of ageing on strength shows that there is a decline in strength with age for all indices of strength assessed, accelerating after the age of 40 or 45 years. Most studies have found a relationship between strength and muscle mass, but despite correcting for changes in muscle mass, a decrease in strength with age is still apparent. It can be concluded from this evidence that functional changes that occur with age will affect strength independent of the muscle mass. Therefore, while the maintenance of exercise should attenuate the decline in strength (Cooper et al., 2011) it will not eliminate the accelerated age-related decline after 40-45 years of age (Runge et al., 2004, Fleg and Lakatta, 1988).

Table 5.2 Summary of studies assessing the effect of ageing on strength

Reference	Type	Participants	Strength Measurement	Changes in strength	Comments
Allied Dunbar National Fitness survey (1992b)	Cross-sectional	n=2369 leg strength n=1968 leg power age 16-74 years As age increases, physical activity levels also decline	Grip strength Knee extension Leg power	Grip strength stable to age 45 years, after which a decline of 3 kgf was observed between 55-60 and 60-55 years.	
Rantanen et al. (1998)	Longitudinal (average 27 year follow-up)	n=3700 men age 45-68 years Japanese living in Hawaii No details of physical activity	Hand grip strength	% change in grip strength per 5 years (4.3 % for 45-49 yrs and 7.5 % for 65-68).	Strength loss was 5-6 times greater in individuals who had lost 5 kg of BM. Due to the age of the participants, it is likely the majority of this was lean mass.
Frontera et al. (1991)	Cross-sectional study	n=200 age 45-78	Peak torque using an isokinetic dynamometer (60 °s) at knee and elbow	Absolute strength decreased with age (18-22 % for different muscles). Difference completely eliminated or reduced when corrected for muscle mass (3-10 %)	A significant proportion of the loss in strength was due to reduced muscle mass. Differences between men and women almost completely diminished when reported relative to muscle mass.
Runge et al. (2004)	Cross-sectional study	n=258 age 18-88 years Healthy patients, staff and family from hospital. No correlation between age and body mass, but BMI increased with age.	Peak power (adjusted for BM) of vertical jump	Peak power dropped by ~40 % between age 20 and 60 (equating to ~7 % per 5 years)	Peak power fell with age, without a reduction in muscle cross section (an indicator of muscle mass) suggesting a crucial role for muscle power in the ageing process.
Nolan et al. (2010)	Cross-sectional study	n=106 males age 30-80 years	Leg muscle strength using a spring gauge (kg)	Leg muscle strength declined by 7 % between age 45-55, and a further 16 % between 55-65	

BM is body mass, BMI is body mass index and kgf is kilogrammes of force.

5.2 Muscular strength and endurance in the UK Fire and Rescue Service

5.2.1 There are currently no standard strength tests implemented for selection to and retention in the UK Fire and Rescue Service; therefore it is difficult to describe the strength status of firefighters. The NSFT does, however, contain several strength based tests with pass standards which could be used for the assessment of the current firefighting work force. There are two discrete strength related tasks in the NFST: the 13.5 m ladder lift and the 13.5 m ladder extension (see Table 2.4 Chapter 2). The ladder extension requires a simulation of raising a ladder to a height of a second storey building and back down again. This task must be completed within 14 s. The ladder lift involves lifting the free end of a simulated ladder pivot to a height of 1.82 m, requiring an equivalent force of 30 kg. Fifty trained firefighters carried out these tests (Rayson et al., 2009c) as part of the validation process. Eight percent of the firefighters failed the test (1/31 men and 3/19 women). So although there are no statistics which describe the current status of the UK Fire and Rescue Service on these tests, there is evidence to show that some trained firefighters are unable to attain this recommended minimum strength standard.

5.2.2 In an attempt to describe the level of muscular strength achievable by UK firefighters, normative data from other cohorts were investigated to give an estimate of mean values and standard deviations. A study by Henderson et al. (2007a) tested grip strength on 306 trainee firefighters (287 men; 19 women). At the end of the 14-week course, the mean grip strength achieved was 65.4 ± 10.8 kg. Another study by Rhea et al. (2004) measured various physical parameters on 20 firefighters (17 men; 3 women), and reported an average grip strength of 58.8 ± 11.2 kg.

5.3 Modelling strength in the UK Fire and Rescue Service

5.3.1 The literature review found that strength loss is generally associated with a loss in lean mass with increasing age, accelerating after the age of around 50 years. This loss of lean mass is usually associated with a concomitant decline in body mass (Jackson et al., 2012, Atlantis et al., 2008). The body composition data in Chapter 3 showed that on average body mass increased throughout the career lifespan of UK firefighters, probably due primarily to the increase in body fat. It is not possible to determine from this whether the increase in body mass means that lean mass is maintained for firefighters, but it is possible to say that even in individuals who maintain their physical activity levels, age associated changes in the structure of the muscle will occur and have an impact of strength parameters. Using the data from Figure 5.1 on the decline in hand grip strength, it is possible to model the impact of increasing the firefighting NPA from 55 to 60 years on strength parameters using the NSFT strength tests as a reference measure.

5.3.2 The participants from the ADNFS decreased their levels of physical activity as they aged, while maintaining a stable body mass. Taking this into consideration, it is possible to estimate the percentage decrease in strength between the ages of 55-60 years for individuals who reduce their level of exercise while maintaining their body mass. Between the ages of 16 and 55 years there was a 13 % reduction in grip strength, which increased to 25 % at 65 years. From this it can be estimated that between the ages of 55 and 60 years there was a further ~6 % decline in hand grip strength for men. For women there was an 11 % decline in hand grip strength between 16 and 55 years, with a further 7% decline between 55 and 60. A worst case scenario for a population which does less exercise with increasing age, resulting in a more rapid decline in lean mass, might expect to experience a decline in strength of 6-7 % between the ages of 55 and 66 years. Similar data were observed by Haisman (1996a), with ~4 % further decline in grip strength between the ages of 55-60 years for both men and women; however there were no details of the cohort from which these data were taken.

5.3.3 Using the data from Rayson et al. (2009c) in which 3 % of men and 16 % of women (all trained firefighters) failed the ladder lift, and using a standard deviation of 11 kg (Henderson et al., 2007a, Rhea et al., 2004), the decline in ladder lift performance has been predicted for men and women, based on the declines described in the ADNFS (Figure 5.2). Based on these data, and if the firefighters follow the population norm by reducing their physical activity as they age, almost all men firefighters and at least 50 % of women firefighters would be able to pass the ladder lift at age 60 years.

5.3.4 To provide more detailed information on exact numbers expected to achieve the standard, Tables 5.3 and 5.4 show the percentage of the men and women firefighting population respectively that would be expected to fail the ladder lift at each age category, using the data from Rayson et al. (2009c), a standard deviation of 11 kg (Henderson et al., 2007a, Rhea et al., 2004) and the age decline reported in the ADNFS (1992b). One man of 31 (3 %) and three women of 19 (16 %) failed the test (Rayson et al., 2009c). Using this statistic along with the standard deviation it is possible to estimate the predicted maximum weight for the cumulative percentage chart. At age 55 years, 10 % of men firefighters and 30 % of women firefighters are predicted to fail the ladder lift. Using the normative data from four Services, roughly 3 % of the firefighting population are women, equating to ~440 women in total. Given that ~10.6 % of the current firefighting population are between the ages of 50-55 years, we estimate that 14 women would not pass the ladder at age 55. Ten percent of the ~43,500 men firefighters (n = 4350) are between the ages of 50-55 years, and using data from Table 5.3, we estimate that 435 of 55 year old men firefighters would fail the ladder lift.

5.3.5 It must be reiterated that this example is a possible ‘worst case’ scenario for firefighters who do not sustain an appropriate level of physical activity throughout their career. Although maintaining lean muscle mass will not abolish the loss in strength with ageing, the declines predicted in Figure 5.2 could be minimised.

Figure 5.2 Predicted decline in grip strength for men and women based on data from the ADNFS (1992b) and average ladder lift score at age 40 from Rayson et al. (2009c)

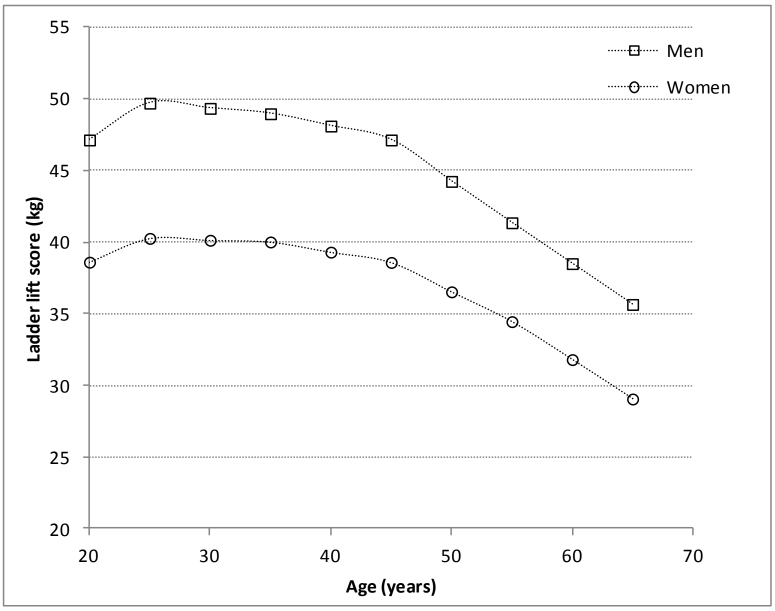


Table 5.3 Estimated cumulative percentage of men firefighters who would be above (shown in green) or below (shown in green) the minimum ladder lift pass standard (i.e. 30 kg), based on the age related decline in strength reported by the Allied Dunbar National Fitness Survey (1992b), and a 3 % failure rate at age 40 (Rayson et al., 2009c)

	Strength score on ladder lift (kg)									
Cumulative Percentage	**Age (Years)**									
	20	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**
1	21.5	24.1	23.7	23.4	22.5	21.5	18.7	15.8	12.9	10.1
5	29.0	31.6	31.2	30.9	30.0	29.0	26.1	23.3	20.4	17.6
10	33.0	35.6	35.2	34.9	34.0	33.0	30.1	27.3	24.4	21.6
15	35.7	38.3	37.9	37.6	36.7	35.7	32.8	29.9	27.1	24.2
20	37.9	40.4	40.1	39.7	30.0	37.9	35.0	32.1	29.2	26.4
25	39.7	42.3	41.9	41.5	40.7	39.7	36.8	33.9	31.1	28.2
30	41.4	43.9	43.6	43.2	42.3	41.4	38.5	35.6	32.7	29.9
35	42.9	45.5	45.1	44.7	43.9	42.9	40.0	37.1	34.3	31.4
40	44.3	46.9	46.5	46.2	45.3	44.3	41.5	38.6	35.7	32.9
45	45.7	48.3	47.9	47.6	46.7	45.7	42.9	40.0	37.1	34.3
50	47.1	49.7	49.3	49.0	48.1	47.1	44.2	41.4	38.5	35.7
55	48.5	51.1	50.7	50.3	49.5	48.5	45.6	42.7	39.9	37.0
60	49.9	52.5	52.1	51.7	50.9	49.9	47.0	44.1	41.3	38.4
65	51.4	53.9	53.6	53.2	52.3	51.4	48.5	45.6	42.7	39.9
70	52.9	55.5	55.1	54.7	53.9	52.9	50.0	47.1	44.3	41.4
75	54.5	57.1	56.7	56.4	55.5	54.5	51.7	48.8	45.9	43.1
80	56.4	59.0	58.6	58.2	57.4	56.4	53.5	50.6	47.8	44.9
85	58.5	61.1	60.7	60.4	59.5	58.5	55.6	52.8	49.9	47.1
90	61.2	63.8	63.4	63.1	62.2	61.2	58.3	55.4	52.6	49.7
95	65.2	67.8	67.4	67.1	66.2	65.2	62.3	59.4	56.6	53.7
99	72.7	75.3	74.9	74.5	73.7	72.7	69.8	66.9	64.1	61.2

Table 5.4 Estimated cumulative percentage of women firefighters who would be above (shown in green) or below (shown in green) the minimum ladder lift pass standard (i.e. 30 kg), based on the age related decline in strength reported by the Allied Dunbar National Fitness Survey (1992b), and a 16 % failure rate at age 40 (Rayson et al., 2009c).

Cumulative Percentage	Strength score on ladder lift (kg)									
	Age (Years)									
	20	25	30	35	40	45	50	55	60	65
1	13.0	14.7	14.5	14.4	13.7	13.0	10.9	8.9	6.2	3.5
5	20.5	22.2	22.0	21.9	21.2	20.5	18.4	16.4	13.7	11.0
10	24.5	26.2	26.0	25.9	25.2	24.5	22.4	20.4	17.7	15.0
15	27.2	28.9	28.7	28.6	27.9	27.2	25.1	23.0	20.4	17.6
20	29.3	31.0	30.9	30.8	30.0	29.3	27.3	25.2	22.5	19.8
25	31.2	32.8	32.7	32.6	31.8	31.2	29.1	27.0	24.4	21.6
30	32.8	34.5	34.4	34.2	33.5	32.8	30.8	28.7	26.0	23.3
35	34.4	36.0	35.9	35.8	35.0	34.3	32.3	30.2	27.6	24.8
40	35.8	37.5	37.3	37.2	36.5	35.8	33.7	31.7	29.0	26.3
45	37.2	38.9	38.7	38.6	37.9	37.2	35.1	33.1	30.4	27.7
50	38.6	40.3	40.1	40.0	39.3	38.6	36.5	34.5	31.8	29.1
55	40.0	41.6	41.5	41.4	40.6	40.0	37.9	35.8	33.2	30.4
60	41.4	43.0	42.9	42.8	42.0	41.4	39.3	37.2	34.6	31.8
65	42.8	44.5	44.4	44.2	43.5	42.8	40.8	38.7	36.0	33.3
70	44.4	46.0	45.9	45.8	45.0	44.3	42.3	40.2	37.6	34.8
75	46.0	47.7	47.5	47.4	46.7	46.0	43.9	41.9	39.2	36.5
80	47.9	49.5	49.4	49.3	48.5	47.8	45.8	43.7	41.1	38.3
85	50.0	51.7	51.5	51.4	50.7	50.0	47.9	45.9	43.2	40.5
90	52.7	54.4	54.2	54.1	53.4	52.7	50.6	48.5	45.9	43.1
95	56.7	58.4	58.2	58.1	57.4	56.7	54.6	52.5	49.9	47.1
99	64.2	65.8	65.7	65.6	64.8	64.2	62.1	60.0	57.4	54.6

5.4 Summary

5.4.1 Muscular strength decreases from the age of about 50 years due to age-related changes in muscle function and a reduction in lean muscle mass

5.4.2 Maintaining a level of physical activity and regular exercise can help to reduce this loss in muscular strength, but will not completely abolish the age-related decline

5.4.3 If firefighters were to follow the same trend as the general population for loss in strength, at age 55 years 30 % of women firefighters and 10 % of men firefighters would not be able to attain the minimum standard of 30 kgf on the ladder lift (from the National Firefighter Selection Tests)

5.4.4 Several assumptions have been made in estimating this statistic:

- Grip strength has been used as the criterion measure of strength, which although gives a good indication of strength, is not an exact predictor of performance on the ladder lift
- The decline in grip strength predicted with ageing has been taken from a data set in which subjects did not maintain physical activity; therefore the declines in strength described are considered a worst case scenario for the Fire Service
- Performance on the ladder lift for incumbent firefighters was described using a very small cohort, so it is an assumption this is reflective of the entire work force.

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6 Heat Tolerance

Victoria L. Richmond, David M. Wilkinson and Mark P. Rayson

6.1 Introduction

6.1.1 The level of heat strain experienced by an individual is a result of the combined physical and environmental components that determine the heat load or stress. Given that firefighters work in challenging environmental conditions with the addition of protective clothing, and that by the nature of the job the physical demands are high, elevated core body temperatures (T_c) are common (Graveling et al., 2001, Selkirk and McLellan, 2004, Richmond et al., 2008) and the risk of sustaining a heat related illness is considerable.

6.1.2 An individual's 'heat tolerance' refers to the extent to which they are able to dissipate the heat they generate and how they respond physiologically to the rise in T_c. When T_c rises, several thermoregulatory responses occur including vasodilation of blood vessels in the skin and production of sweat. These processes allow heat to be lost via evaporation, conduction and convection in an attempt to maintain a stable T_c. The temperature at which these processes start to occur, and the amount of heat that can be lost via these routes, vary considerably between individuals.

6.1.3 There are several factors which cause an individual's response to heat stress to differ, including aerobic fitness (Havenith et al., 1998, Cheung and McLellan, 1998), hydration status (Gonzalez-Alonso et al., 1998) and body composition (Havenith et al., 1998, Havenith et al., 1995b). For the purposes of this review, the variable that will be discussed is the impact of ageing on heat tolerance and thermoregulatory responses, in a hot, humid environment. To address the question, "how does heat tolerance change with age", MEDLINE, the U.S. National Library of Medicine's bibliographic database of over 19 million references to journal articles in life sciences and biomedicine, was searched using PubMed. A clinical queries search using the categories 'prognosis' and 'narrow' and the search terms 'heat tolerance AND ageing' returned 1 result in the clinical study categories (filters set for English and species human); however, this study was not relevant. Consequently, known references have been reviewed and all relevant references cited in those papers, books and reports were further reviewed if they helped explain the change in heat tolerance with age.

6.1.4 Just two papers will be discussed that provide evidence of the changes in heat tolerance with ageing (summarised in Table 6.1). A cross-sectional study by Havenith et al. (1995a) investigated the T_c response of 56 volunteers (age 20 to 73 years) to cycling in a warm, humid environment (35 °C, 80 % relative humidity (RH)). Age was not correlated with final rectal temperature (T_{re}), but absolute VO_2max was significantly correlated with final T_{re}. The author concluded that thermoregulatory and sweating responses are closely related to VO_2max and physical activity levels. Therefore, based on the predicted decline in aerobic fitness with increasing age in Section 2.2, one would expect impaired heat tolerance with ageing.

6.1.5 A study by Pandolf highlighted another important factor for consideration. Two groups of men (9 young men age 21.4 ± 2.4 years and 9 older men age 46.4 ± 4.6 years) undertook ten days of acclimatisation in a hot, dry environment (49 °C, 20 % RH). The exercise protocol consisted of 2 x 50 minutes of treadmill walking per day. On day one, the older group exercised for an additional 27 minutes to the younger group, with a lower T_{re} and heart rate at the end of exercise; however, by the last day of acclimatisation there was no difference between groups. These two groups were matched for VO_2max, and the author concluded that the superior thermoregulatory response on day one in the older group was due to the greater amount of physical activity carried out, and thus improved thermoregulatory function. The results from this paper highlight two important facts; 1) when matched for VO_2max and acclimatised to the same level, age does not affect the thermoregulatory response, and 2) performing regular physical activity (in addition to sustaining a stable VO_2max) is important for maintaining thermoregulatory function.

6.1.6 The evidence clearly shows that any differences between age groups in heat tolerance is due to differences in aerobic activity (Pandolf et al., 1988) and the decrease in VO_2max with age (Kenney and Hodgson, 1987, Havenith et al., 1995a), rather than age *per se*. However, changes in aerobic fitness and levels of physical activity do impact on heat tolerance, and Section 2.2 in this report shows that VO_2max is expected to decline with ageing in the firefighting population. As a result it might be expected that at around the age of 45 years when VO_2max starts to decline, heat tolerance will be impaired.

6.2 Summary

6.2.1 Ageing *per se* does not affect heat tolerance or thermoregulatory function

6.2.2 As VO_2max declines, heat tolerance is impaired

6.2.3 Performing regular physical activity is important for maintaining optimum thermoregulatory function, regardless of VO_2max

6.2.4 Previous evidence (Chapter 4) suggests that VO_2max in firefighters is expected to decline with ageing.

Table 6.1 Summary of studies investigating the effect of ageing on heat tolerance

Reference	**Type**	**Participants**	**Measurements**	**Observations**
Havenith et al. (1995a)	Cross-sectional study	N=56 41 men, 15 women	35 °C, 80 % Relative Humidity Exercised on cycle ergometer at 60 W for up to 60 min or until exhaustion	There was no correlation between final rectal temperature and age, but T_{re} was significantly correlated with absolute VO_2max .
Pandolf (1998)		Nine young men (mean age 21.4 years) and nine older men (mean age 46.4 years)	Men were heat acclimated over 10 days, by performing 2 x 50 minutes treadmill walking per day in a hot, dry environment (49 °C, 20 % RH)	Tolerance time on day one was longer (27 min) and T_{re} and HR were lower for the young males. By the end of acclimatisation there was no difference between groups. The better initial performance in the young group was attributed to greater weekly activity, which was negated following acclimatisation.

6.3 References

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7 Health and Age

Anthony N Williams

7.1 Introduction

7.1.1 Past reviews of age and fitness for firefighting have all suggested that there will be a significant increase in chronic disease with age, and that this in turn will have a significant impact on numbers fit for firefighting. This review has therefore considered the potential increase in chronic disease in detail in order to clearly quantify the likely increase in chronic disease with an increase in NPA. In several areas this has demonstrated a very small increase or none predicted, however it is important to show how we have come to this conclusion. This does make this Chapter long and detailed.

7.1.2 A specific search was carried out in ProQuest from both Medline and Embase including the terms ‘aging’ or ‘ageing’ or ‘age’ and the terms ‘firefight[*3] or fire fight[*3] or fire-fight[*3] or fireman or firemen or fire man or fire men or fire service[*1] or fire personnel or “emergency service personnel”. This generated 272 results. The great majority of these were not relevant to this review, and for each topic further searching was required. While systematic searching proved useful to get an overview of the literature available, none of the topics could be addressed only through systematic searching. Many of the sources used were either not published on the standard medical databases, or had to be identified through widening the search, lateral thought and intuition. There may well be other studies of great value to the topics that were not found. This area of research is likely to become a well-trodden route as pension ages are increased while the population becomes less fit and succumbs to the ills attributable to lifestyle. Subsequent reviews should therefore benefit from other researchers spreading wider and digging deeper while further primary research adds to our knowledge base.

7.1.3 Firefighting is dangerous. The potential hazards are numerous, with exposure to trauma and heat, and to a variety of toxic or noxious substances. The exposure of individual firefighters will however be varied, any exposure may be brief; therefore the overall risk to health from a lifetime of firefighting may not be significantly greater than for the general public.

7.1.4 There have been specific studies of exposure, for example many firefighters exposed for prolonged periods to dust in the aftermath of 911 have developed substantial health effects. No studies, however, have shown a consistent increase in risk overall. The Industrial Injuries Advisory Council requires a doubling of risk in order to prescribe a disease relating to firefighting. A study in 2010 failed to identify any consistent evidence for elevated risk of cancer in fire-fighters, and studies of coronary heart disease were ‘inconclusive’ (Graveling and Crawford, 2010).

7.1.5 There is a clear association between onset of chronic disease and age. There is also an association between increasing incidence of acute conditions with age and a more prolonged recovery time away from active duty. These conditions will affect the ability of firefighters to work safely and effectively, and they will affect sickness absence rates. Where firefighters are permanently unable to work in their role, the conditions will also affect levels of ill health retirement. The incidence of chronic disease, and recovery rates, are also very closely associated with lifestyle including physical fitness, obesity, smoking and alcohol use. This review has considered mortality and common chronic diseases in greater depth.

7.2 Mortality rates

7.2.1 The simplest indication of the impact of chronic disease is mortality rate. The impact of the disease will be substantial well before death, but statistics on morbidity are not available for most conditions, so mortality statistics are an important indicator of the increase in the impact of chronic disease with age. Table 7.1 includes mortality rates for the most common chronic diseases likely to impact on firefighters.

Table 7.1 Death rates per thousand population in England and Wales in 2010, age-adjusted

Age		25-34	35-44	45-54	55-64	65-74
All causes	Men	0.76	1.53	3.22	8.28	20.51
	Women	0.38	0.92	2.14	5.29	13.09
All diseases of circulatory system	Men	0.08	0.31	0.92	2.44	6.37
	Women	0.04	0.12	0.34	0.88	3.08
Ischaemic heart disease	Men	0.02	0.15	0.58	1.60	3.75
	Women	0.01	0.04	0.13	0.38	1.37
Cerebrovascular disease	Men	0.01	0.05	0.12	0.30	1.09
	Women	0.01	0.03	0.10	0.21	0.80
Diabetes	Men	0.01	0.02	0.03	0.06	0.18
	Women	0.01	0.01	0.02	0.04	0.12
Neoplasms	Men	0.09	0.26	0.96	3.44	8.79
	Women	0.01	0.35	1.05	2.89	6.08
Respiratory disease	Men	0.02	0.06	0.16	0.67	2.33
	Women	0.02	0.05	0.12	0.48	1.61

7.2.2 Morbidity and mortality rates are usually expressed in ten year age bands. The median value will not be central because of the increase with age, so a graphical representation of the increase needs to assume a shift to the right of the median age for the group. Thus a mortality rate for ischaemic heart disease for 55-64 year old men is 1.6 per thousand per annum. This does not mean that the rate for 60 year olds is 1.6. The rates for the ten year age bands either side would suggest an approximate age of 62 for this rate to be reached. Rates are usually, as in this case, age-adjusted to reflect the rates against the total population at each age.

7.2.3 These death rates are illustrated graphically below to demonstrate the rate of rise.

Figure 7.1 Death rates per thousand, males, England and Wales 2010

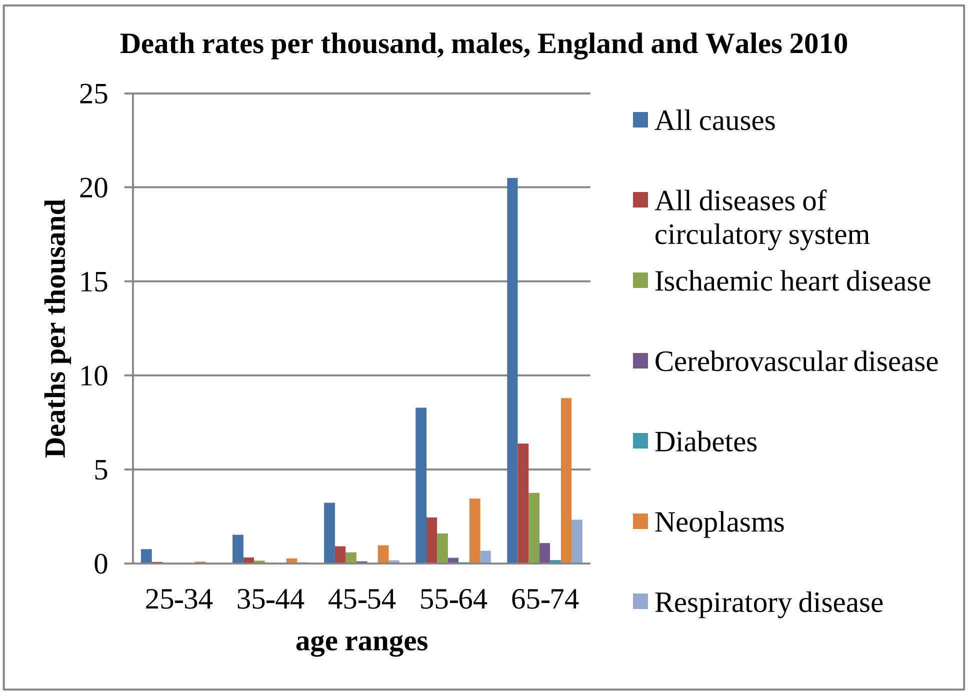
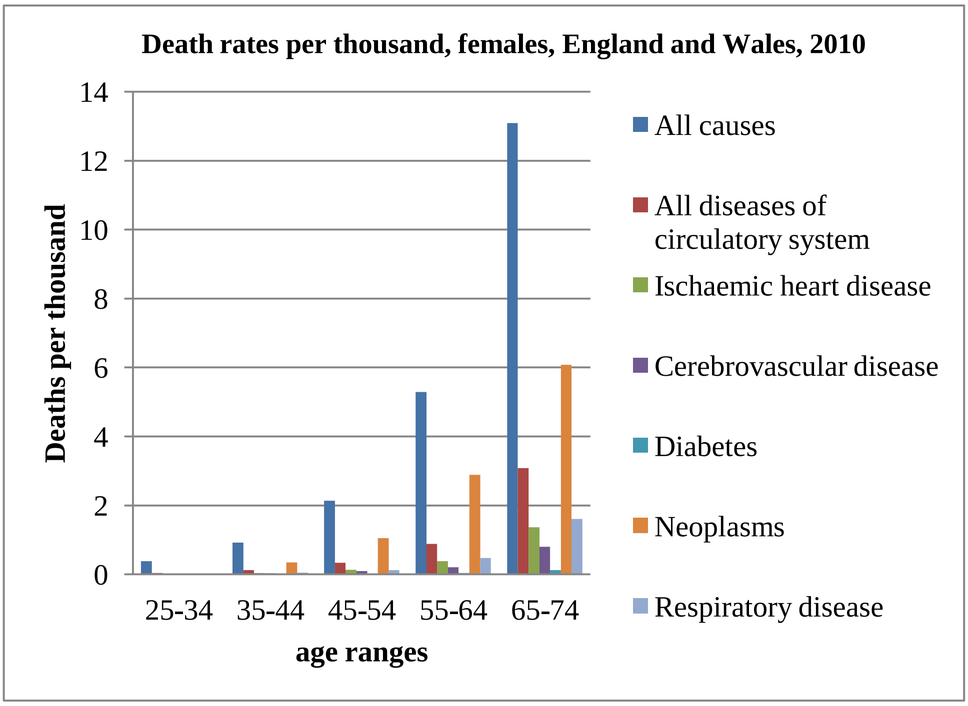


Figure 7.2 Death rates per million, females, England and Wales, 2010



7.2.4 Around 80 % of mortality in the age range 45-54, and above, results from circulatory disease, neoplasms and respiratory disease. These are likely to be the main causes of morbidity affecting firefighter fitness and ill health retirement, and will be considered in more detail below.

7.2.5 Several older studies (pre-1990) have shown increased mortality from various chronic diseases among firefighters compared to the general population, but often with very wide confidence intervals (Sardinas et al., 1986, Musk et al., 1978). New research has shown the opposite, the new research is based on larger studies and has been confirmed by actuarial studies of UK firefighters. Firefighters are expected to be reasonably fit, so a significant healthy worker effect could be expected. A recent study, among firefighters in Hamburg, Germany, showed a significant healthy worker effect with an overall standardised mortality ratio (SMR) of 0.79 (95 % CI, 0.74-0.84) (Wagner et al., 2006). This would suggest that figures for the general population should be adjusted down by this amount. A review by the Government Actuary's Department in 2007 confirmed this, showing that men firefighters lived between one and two years longer than the average UK population, while women firefighters lived nearly a year longer (Government Actuary's Department, 2007). Trends in ill-health retirement suggested that this should increase to a longevity of plus three years. The difference increased with increased age at retirement, suggesting that working longer as a firefighter increased longevity. A study of hazardous occupations found that firefighting was 23rd out of 30 (Roberts, 2002) and this was attributed to considerable investment and effort put into health and safety by fire authorities in consultation with the Health and Safety Executive (Bain et al., 2002). A healthy worker effect adjustment down by 20 % will therefore be used in this study in relation to chronic disease morbidity and mortality.

7.2.6 For men in England and Wales, the mortality data indicate a mortality of 3.2 per thousand per annum at age 50, and a mortality of 8.3 per thousand per annum at age 60, suggesting a mortality at age 50-54 of around 4 per thousand per annum and at age 55-59 of around 7 per thousand per annum. This suggests an increase of around 75 % for the age group 55-59 compared to 50-54, and applying a healthy worker adjustment the expected mortality from all causes would be 5.6 per thousand per annum for ages 55-59.

7.2.7 For women in England and Wales, the mortality data indicate a mortality of 2.1 per thousand per annum at age 50, and a mortality of 5.3 per thousand per annum at age 60, suggesting a mortality at age 50-54 of around 2.7 per thousand per annum and at age 55-59 of around 4 per thousand per annum. This suggests an increase of around 50% for the age group 55-59 compared to 50-54, and applying a healthy worker adjustment the expected mortality from all causes would be 3.2 per thousand per annum for ages 55-59.

7.3 Cardiovascular disease

7.3.1 Cardiovascular disease represents a major burden for populations and firefighters do not escape. It includes coronary heart disease, angina, cerebrovascular disease and peripheral vascular disease. Acute events represent one of the most likely causes of sudden death among firefighters, particularly during operational activity. There is no evidence that firefighters have significantly more acute events than the general population (Friel and Stones, 1992, Musk et al., 1978, Sardinas et al., 1986, Wagner et al., 2006), however there is evidence to link these events with an episode of high physical demand (Kales et al., 2003, Holder et al., 2006). This suggests that firefighters who have an acute ischaemic cardiac event while firefighting were going to have such an event at some point, but that the intense physical exertion on duty precipitated this event (Mittleman and Mostofsky, 2011, Smith et al., 2012a). A study looking at abnormal cardiovascular function during and after exercise tests found that firefighters with relatively low fitness (less than 12 METs which equates to VO_2 max around 42 $mL \cdot kg \cdot min^{-1}$) had significantly more abnormalities of ECG and other autonomic exercise responses (slow HR recovery, low peak HR, blood pressure response peak >220/90), suggesting that firefighters with low fitness were more at risk of acute ischaemic cardiac events while firefighting (Baur et al., 2012c).

7.3.2 A recent study of 735 male members of a county fire service found that in 2008 35 % were normal weight compared to 34 % of the general public, 54 % were overweight compared to 42 % of the general public and 11 % were obese compared to 24 % of the general public. Eleven percent of firefighters had waist circumference greater than 102 cm compared to 34 % of the general public (Munir et al., 2012). This suggests that firefighters are similar in levels of overweight to the majority of the general public, but their role prevents them from reaching higher levels of obesity and morbid obesity. In a population that has a similar fitness and health profile to the general public, it is appropriate to consider the prevalence of cardiovascular disease in the UK population, although levels would be expected to be significantly lower because fewer firefighters approach morbid levels of obesity. Obesity levels in firefighters have been considered in more depth in Chapter 3.

7.3.3 Not all firefighters with cardiovascular disease are unfit for firefighting, but the onset of symptoms is associated with substantial risk factors for early morbidity and mortality with an associated impact on operational safety and effectiveness (Smith et al., 2012a). The statistics for mortality rates are changing. The upward pressures from a society that is increasingly sedentary and obese are countered by downward pressures from preventive treatment (Scarborough et al., 2010). Complex genetic and environmental factors also play a part, and the pattern of disease has changed significantly over the last half century.

7.3.4 There is a social gradient, with women in manual employment five times as likely to die from coronary heart disease as women in higher managerial and professional employment, and men in manual employment are three times as likely to die as men in higher managerial and professional employment (Scarborough et al., 2010). Coronary heart disease (CHD) risk is closely related to obesity, and the 2008 Health Survey of England showed 19 % of women in the highest income quintile were obese compared to 32 % of women in the lower income quintile which could explain most if not all the variation in CHD mortality between these social groups (NHS Information Centre, 2008). There was no apparent difference in obesity levels between economic groups noted in men.

7.3.5 Geographical differences in myocardial infarction (MI) remain, with Scotland and the North of England highest and the South of England the lowest. Changes in risk factors have, however, led to substantial improvements and the incidence rate of MI in Scotland has decreased by about 25 % between 2000 and 2009 in both men and women. Statistics are only available for some years, and a comparison of figures for 2005-7 indicates an incidence of MI of between 20 % and 35 % higher in Scotland for both men and women. This difference does not stop at the border, and higher levels are also noted in North of England(Scarborough et al., 2010).

7.3.6 Fitness for firefighting after MI will depend on residual function, which in turn will depend predominantly on signs and symptoms of angina or heart failure. Analysis of statistics for these will give an indication of the relative effect on numbers unfit to firefight from these conditions. There are surprisingly few studies that quantify return to work rates after MI where work is defined (Slebus et al., 2007). There are papers that demonstrate it is entirely feasible for post-MI patients to return to extreme levels of physical activity safely (Kennedy et al., 2012), but there are no sources that give any figures for how many firefighters might return to operational firefighting after MI. Early percutaneous coronary intervention or fibrinolysis can lead to aborted infarct in 25 % of patients (Verheugt et al., 2006) but this does not apply to all infarct patients.

7.3.7 Incidence rates of angina from the General Practice Research Database (GPRD) indicate that overall in UK incidence rates were 75 % higher in men compared to women, with the highest incidence (as opposed to prevalence) in the 65-74 age group. Differences were noted between the GPRD and national surveys. The GPRD has significantly lower estimates, and is probably more accurate as it is linked to the Quality Outcomes Framework, the basis for a significant proportion of General Practitioner (GP) remuneration.

7.3.8 Angina is associated with high risks of an acute ischaemic event and the requirement for revascularisation. It is not generally compatible with firefighting unless it is variant angina, very mild and fully controlled with medication and lifestyle change, or unless it has been effectively treated with revascularisation (Antman et al., 2000, Diamond and Forrester, 1979, Pryor et al., 1993). Revascularisation can be very effective in enabling a firefighter to return to active duty; however studies show that this is not universal. Recovery rates do vary, and poor motivation to address lifestyle issues inevitably increases morbidity after a revascularisation procedure. Studies indicate that around 40-60 % of patients are symptom free after treatment (Parisi et al., 1992, Henderson et al., 2003), and it could therefore be assumed that these could return to active operational service as firefighters. Quality of life measures suggest that this figure could be substantially smaller, perhaps 20 % (Pocock et al., 2000). Based on this evidence, for the purposes of this study it will be assumed that 50 % of individuals who develop angina will no longer be fit for firefighting.

7.3.9 As noted above, there are no reliable sources of data that allow a prediction of the percentage of firefighters likely to return to operational duty after an MI. Ill health retirement data do not always distinguish between the different types of heart disease, so an overall estimate for ischaemic heart disease is needed. An assumed rate of 50 % remaining fit to firefight with treatment will be used to predict ill health retirements assuming normal population levels of heart disease.

7.3.10 Age-specific prevalence rates for combined cardiovascular disease and stroke have been measured by the General Household Survey and show an increase for men over 45 between 1988 and the mid-2000's with a possible slight fall since then, and for women a corresponding increase between 1988 and the mid-2000's and definite fall since (Scarborough et al., 2010).

7.3.11 The distinction between stroke and transient ischaemic attack (TIA) is controversial. A person may have all the clinical signs and symptoms of a stroke with permanent sequelae but no infarction seen on imaging. Alternatively a person may have a transient event with apparent full clinical recovery but clear infarction seen on imaging. The distinction is therefore essentially arbitrary with usually a 24 hour cut-off for recovery from symptoms defining 'transient'. There will inevitably be differences in reporting, with some or most TIAs reported as strokes, but strokes will never be reported as TIAs. Many non-vascular events such as hemiplegic migraine or epilepsy may also be reported as TIAs. Epidemiological studies suggest that the ratio of stroke to TIA is around 3:1 (Rothwell et al., 2004).

7.3.12 A systematic review of studies for those who enter vocational rehabilitation showed the percentage returning to work varied between 12 % and 49 % (Baldwin and Brusco, 2011). A large cohort study in Denmark comparing individuals with intracerebral infarction, subarachnoid haemorrhage and intracerebral haemorrhage found 62% were gainfully employed two years after stroke (Hannerz et al., 2011). Only a small percentage of patients who have had a TIA have actually sustained an identifiable infarction on MRI, with one study using the current American Heart Association definition for TIA found 11 % with demonstrable acute infarction (Al-Khaled et al., 2012).

7.3.13 For the purposes of this study, it will be assumed that all firefighters who have had a stroke will be permanently unfit, while all firefighters who have had a TIA will regain full fitness. Figures will be adjusted by the healthy worker effect, a 20 % reduction as suggested above. Where reported 'stroke' includes TIA, the figure will be adjusted down by 40 % to allow for TIAs recovering fully, and for the healthy worker effect.

7.3.14 The data in Tables 7.2-7.5 define stroke as the consequence of an interruption to the flow of blood to the brain, which is assumed to include TIA. Coronary heart disease (CHD) was defined as reporting either angina or MI. Cardiovascular disease (CVD) was defined as reporting either angina or myocardial infarction or stroke or heart murmur or irregular heart rhythm. The tables come from different sources, using different disease categories.

Table 7.2 Prevalence of ever being diagnosed with vascular diseases per thousand population by age, England, 2006 (Craig and Mindell, 2008)

Age range		CHD	Stroke	MI	Angina	CVD
25-34	Male	2	0	2	1	4.7
	Female	1	1	0	1	5.7
35-44	Male	6	5	6	3	56
	Female	3	4	1	2	78
45-54	Male	36	12	21	24	109
	Female	13	9	7	12	103
55-64	Male	106	30	63	80	185
	Female	35	23	16	32	152
65-74	Male	208	71	144	142	341
	Female	100	42	33	83	212

Note: CHD = Coronary heart disease, MI = myocardial infarction, CVD = Cardiovascular disease.

Figure 7.3 Prevalence of vascular diseases, males, England 2006

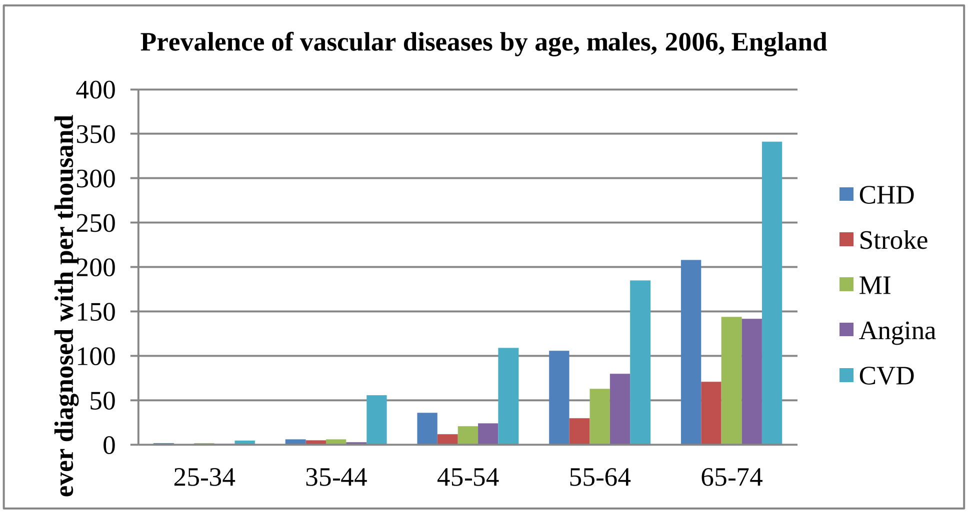


Figure 7.4 Prevalence of vascular diseases, females, England 2006

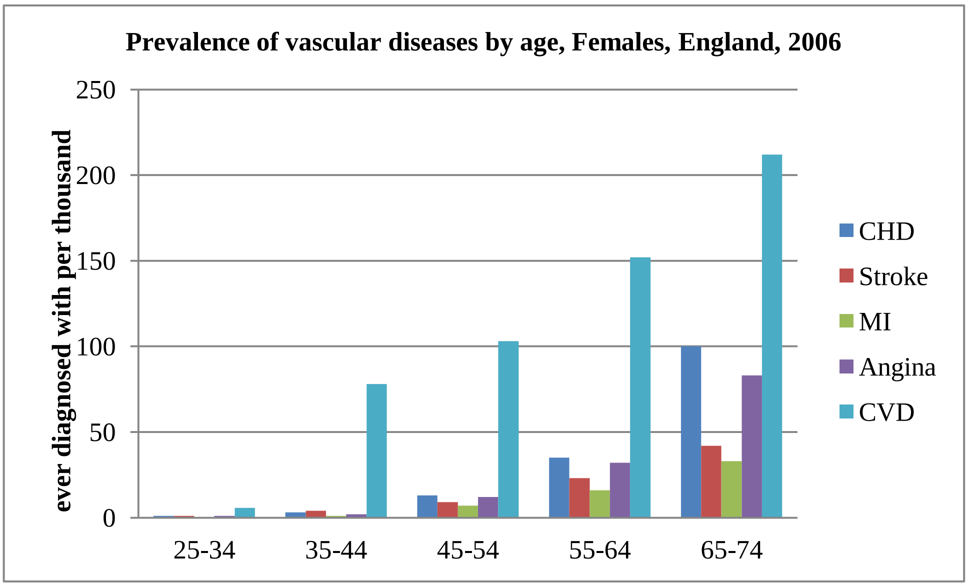


Table 7.3 Prevalence of ever being diagnosed with vascular diseases by age per thousand population, Scotland, 2008 (Corbett et al., 2009)

Age range		CHD	Stroke	MI	Angina	CVD
25-34	Male	0	0	0	0	49
	Female	0	0	0	0	64
35-44	Male	5	13	2	4	68
	Female	0	0	0	0	57
45-54	Male	30	8	17	23	103
	Female	24	19	13	16	129
55-64	Male	131	33	76	93	220
	Female	74	32	23	64	189
65-74	Male	219	58	134	144	358
	Female	159	71	67	130	309

Figure 7.5 Prevalence of vascular diseases, males, Scotland 2008.

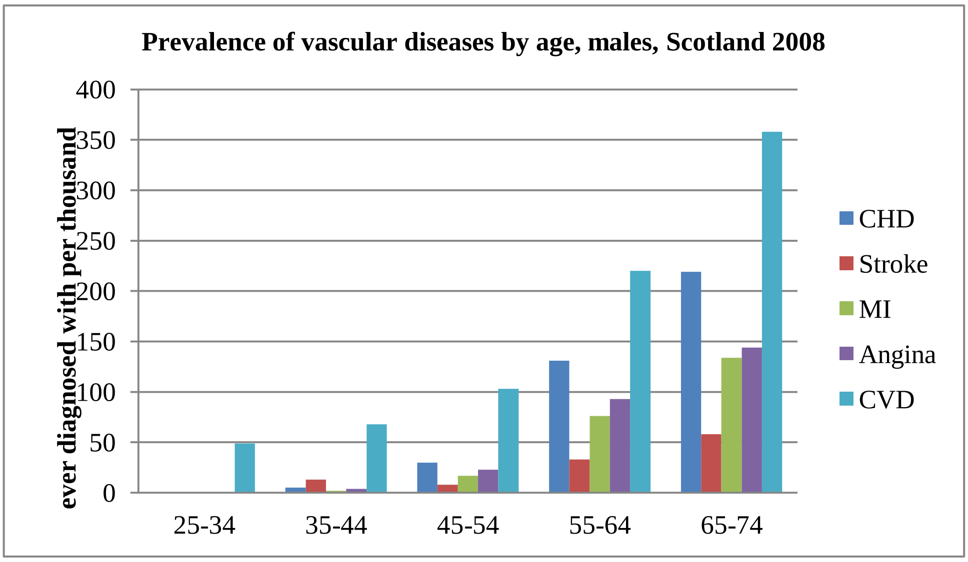


Figure 7.6 Prevalence of vascular diseases, females, Scotland 2008

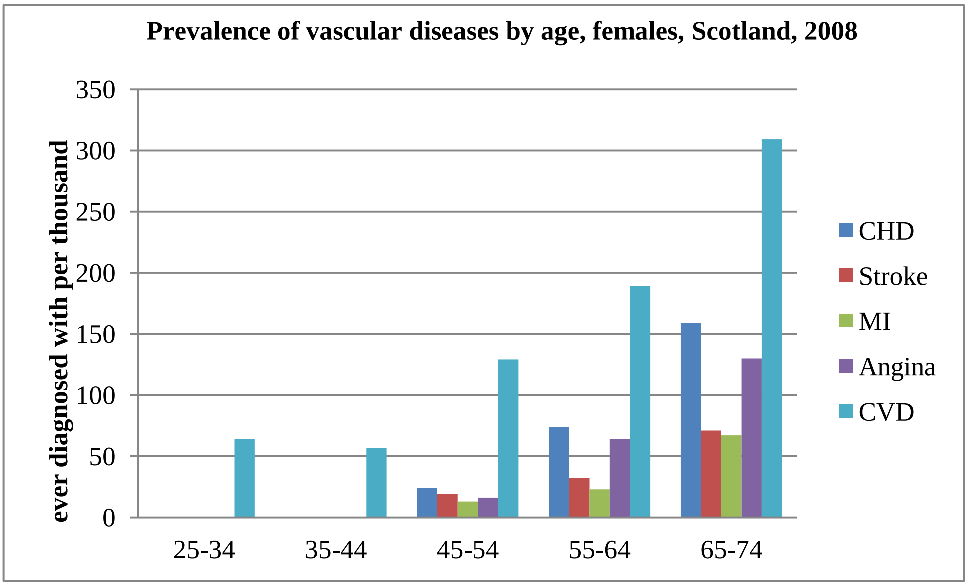


Table 7.4 Prevalence of vascular diseases per thousand population by age, Wales, 2008 (Crudge et al., 2009)

Age range		MI	Stroke	Angina	Heart failure	Any heart condition
25-34	Male	0	0	0	0	10
	Female	0	0	0	0	10
35-44	Male	10	0	0	0	20
	Female	0	10	0	0	10
45-54	Male	30	01	10	10	40
	Female	10	10	20	0	40
55-64	Male	80	40	60	20	150
	Female	20	20	40	10	80
65-74	Male	160	80	140	40	290
	Female	60	40	100	20	190

Figure 7.7 Prevalence of vascular diseases, males, Wales 2008

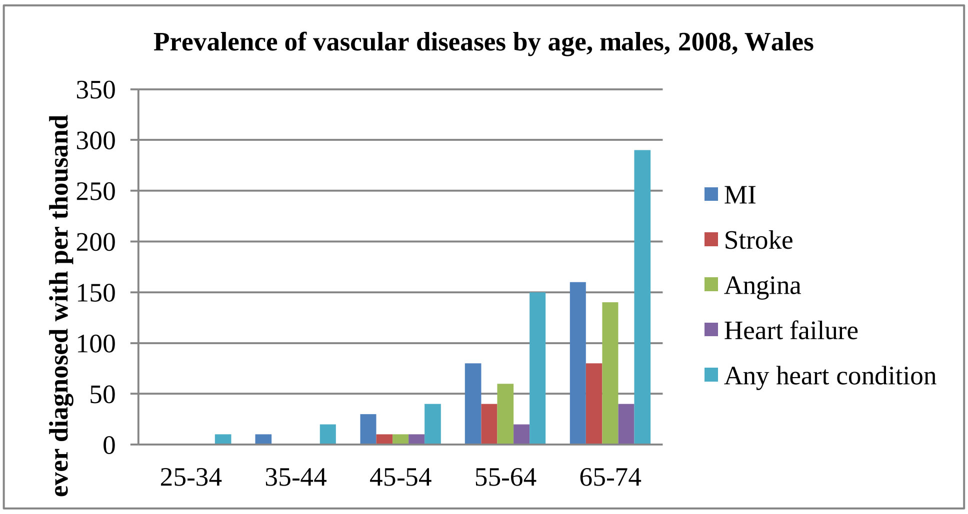


Figure 7.8 Prevalence of vascular diseases, females, Wales 2008

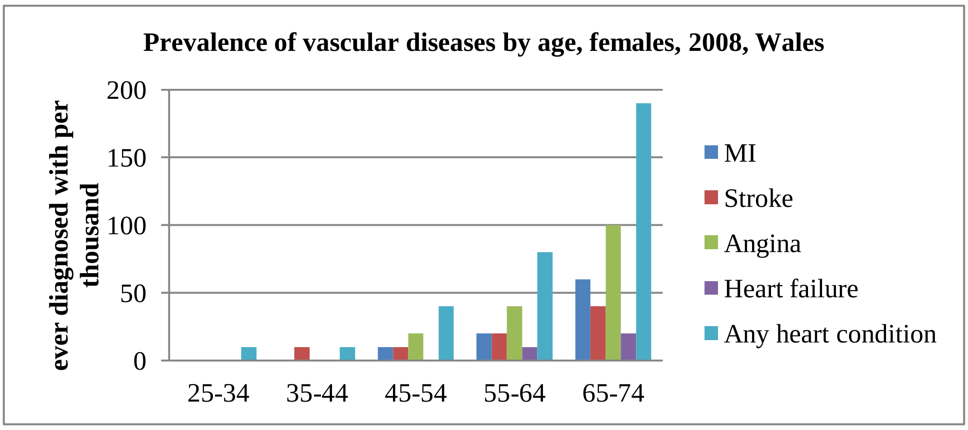


Table 7.5 Prevalence of vascular diseases per thousand population by age, Northern Ireland, 2005/6 (Central Survey Unit, 2006)

Age range		MI	Stroke	Angina
25-34	Male	10	10	0
	Female	0	0	0
35-44	Male	0	0	0
	Female	0	0	0
45-54	Male	50	10	50
	Female	0	10	40
55-64	Male	110	20	130
	Female	20	20	50
65-74	Male	160	60	200
	Female	60	30	150

Figure 7.9 Prevalence of vascular diseases, males, NI 2005/6

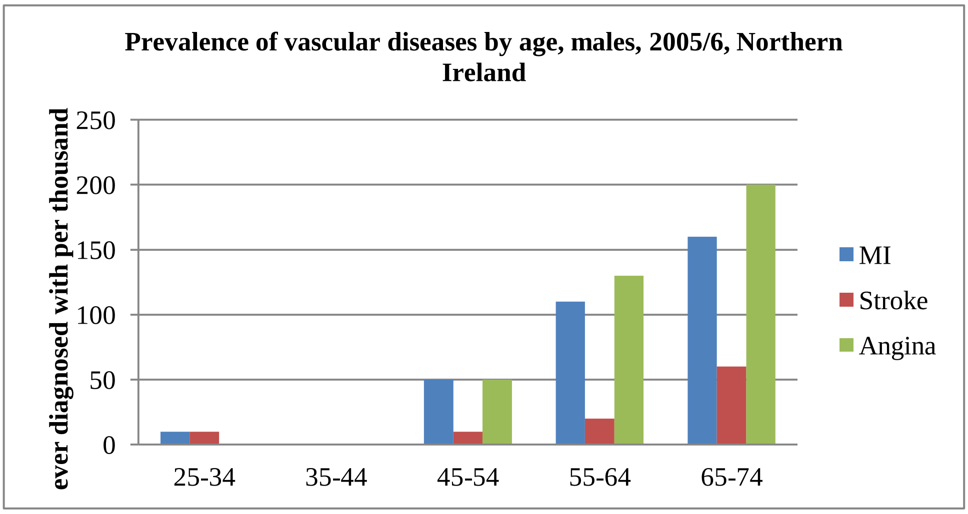
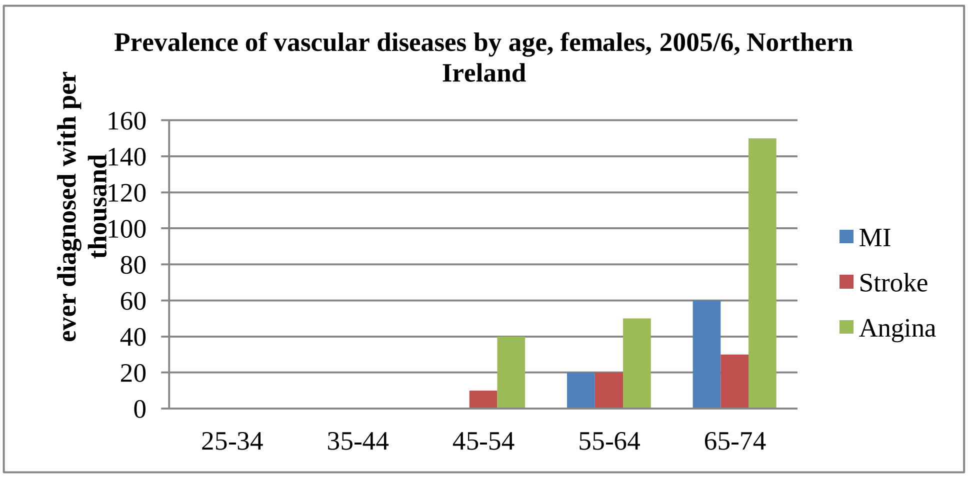


Figure 7.10 Prevalence of vascular diseases by age, females, NI 2005/6



7.3.15 From the figures above, estimates have been produced in Table 7.6 for the prevalence and percentage likely to be unfit for firefighting at age 50-55 and 55-60 assuming that general population rates apply to firefighters. As noted above, the process used to extrapolate to these figures will introduce a significant margin of error, so they are guideline figures only. There was no figure for all coronary heart disease for Northern Ireland so an estimate was derived from the figures for angina and MI.

Table 7.6 Expected prevalence of vascular diseases in men and expected percentage unfit for firefighting in the four Nations assuming general population rates apply without a healthy worker effect. (These figures will be cumulative, so if 10 per 1000 will retire during ages 50-55 and the rate increases to 20 per 1000 for 55-59, a further 10 per 1000 will retire during the subsequent five year age band).

		Heart disease/1000		Stroke/1000	
		total	total unfit	total	total unfit
50 - 54	England	50	25	15	9
	Scotland	50	25	10	6
	Wales	60	30	15	9
	Northern Ireland	90 (est)	45	10	6
55 - 59	England	85	43	22	13
	Scotland	105	53	25	15
	Wales	115	63	30	18
	Northern Ireland	140 (est)	70	15	9
60 - 64	England	130	65	45	27
	Scotland	160	80	40	24
	Wales	185	93	50	30
	Northern Ireland	190 (est)	95	30	18
65 – 69	England	180	90	60	36
	Scotland	200	100	55	33
	Wales	250	125	70	42
	Northern Ireland	240 (est)	120	50	30

Table 7.7 Expected prevalence of vascular diseases in women and expected percentage unfit for firefighting in the four Nations assuming general population rates apply. (These rates will be cumulative, as above).

		Heart disease		stroke	
		total	total unfit	total	total unfit
50 - 54	England	15	8	15	9
	Scotland	30	15	20	12
	Wales	45	23	10	6
	Northern Ireland	40 (est)	20	10	6
55 - 59	England	25	13	20	12
	Scotland	60	30	30	18
	Wales	65	33	15	9
	Northern Ireland	60 (est)	30	15	9
60 - 64	England	50	25	30	18
	Scotland	95	48	40	24
	Wales	100	50	25	15
	Northern Ireland	100 (est)	50	25	15
65 - 69	England	85	43	45	27
	Scotland	135	68	60	36
	Wales	160	80	35	21
	Northern Ireland	150 (est)	75	30	18

7.4 Neoplasms

7.4.1 Firefighters are potentially exposed to a wide variety of toxic agents because of the nature of their emergency response to situations where these agents may be released or produced. A major IARC study found that there was limited evidence in humans for the carcinogenicity of occupational exposure as a firefighter, and concluded that occupational exposure as a firefighter was possibly carcinogenic to humans (Group 2B) (IARC, 2010). Studies were inconsistent and few showed statistical significance. After meta-analysis, the strongest evidence of association was for testicular cancer, prostatic cancer and non-Hodgkin lymphoma. No studies have clearly demonstrated an exposure-response relationship and there is insufficient evidence to provide a useable statistic for relative risk. We have therefore considered firefighters to be at the same risk for cancer as the general public. The incidence of many cancers is known to increase substantially with obesity and other lifestyle factors, so a 'healthy worker effect' will be expected.

7.4.2 The rate of cancer incidence will increase with age, and Tables 7.8 and 7.9 show the age-specific incidence of new cancer diagnoses in each five year age band. Overall cancer incidence and rates for just the three most common cancers for men and women have been included. For each gender the three most common represent significantly greater than 50 % of the total numbers. The tables exclude non-melanoma skin cancer.

Table 7.8 Male age-specific rates of cancer per 1000 population of newly diagnosed cases of cancer, England 2010 (Office of National Statistics, 2010a)

Age	40-44	45-49	50-54	55-59	60-64	65-69	70-74
All cancers excl nmsc	**1.17**	**1.94**	**3.67**	**6.71**	**11.30**	**17.51**	**23.00**
Colon and rectum	0.11	0.23	0.45	0.80	1.65	2.53	3.18
Trachea, bronchus & lung	6.2	16.4	36.8	85.1	142.2	240.6	345.8
Prostate	2.9	15.2	59.2	163.8	330.0	575.2	704.5

Table 7.9 Female age-specific rates of cancer per 1000 population of newly diagnosed cases of cancer, England 2010

Age	40-44	45-49	50-54	55-59	60-64	65-69	70-74
All cancers excl nmsc	**2.51**	**3.91**	**5.60**	**6.94**	**9.79**	**12.49**	**13.91**
Colon and rectum	0.11	0.19	0.34	0.55	0.94	1.49	1.84
Trachea, bronchus and lung	0.05	0.16	0.34	0.66	1.11	1.70	2.21
Breast	1.29	2.16	2.78	2.65	3.50	3.98	3.16

7.4.3 These data suggest that there would be a doubling of incidence of all cancers for men from ages 50-55 to 55-60 but for women it is only around 25 % higher.

7.4.4 Many cancers require substantial treatment including surgery, chemotherapy and radiotherapy, and the impact of these makes it very unlikely that a firefighter could continue operational work during treatment. However after treatment for the majority of cancers there is no medical reason why there should be a substantial long-term impairment. A return to full operational duty can therefore be expected. Some cancers will have significant residual impairments or scarring, for example where significant muscle damage has arisen, or there is a permanent colostomy or ileostomy, or substantial organ damage such as loss of a lung.

7.4.5 Large bowel cancers lead to permanent stomas in around 3 % of cases of low rectal cancer (Bailey et al., 2003). Five-year survival rates in England are 55 % for both sexes (Office of National Statistics, 2012). The other main problem following large bowel surgery is increased frequency of bowel movement which is not expected to be a major problem for firefighters. This would suggest that there will be an increase in large bowel cancer incidence of around 40 % between ages 55 and 59.

7.4.6 Lung cancer has a relatively poor return to work rate compared to other cancers, probably because of the overall poor prognosis. Five-year survival rates in England are only around 9 % for men and 11 % for women (Office of National Statistics, 2012). In those with a good prognosis, lobectomy is likely to be part of their treatment, with significant subsequent loss of physical capacity. While some firefighters will be able to return to active operational duty, it will be assumed that this figure will be small.

7.4.7 Most men are expected to make a good longer term recovery from prostate cancer, and most should be able to return to a heavy manual role. Five year survival is around 80 % (Office of National Statistics, 2012).

7.4.8 The incidence of breast cancer would be lower between ages 55 and 59 than previous five year age bands, and slightly higher from age 60 to 69. Shiftwork is considered a probable carcinogen related to breast cancer, however there are no clear statistics available to predict the increase in expected breast cancer among shift workers because it appears to be small (Hansen and Stevens, 2011). The effect is unlikely to make any statistical difference to the numbers of firefighters expected to ill-health retire with breast cancer. Five year survival is around 85 % (Office of National Statistics, 2012). Treatment for breast cancer generally takes around six to nine months to complete from diagnosis through surgery, radiotherapy and where appropriate, chemotherapy. Surgical activity levels suggest a ratio of total mastectomy to 'lumpectomy' of 1:2, and axillary clearance in around 30 % of cases. Women are unlikely to cope with firefighting duties during treatment and may well require a period of several months for physical recovery afterwards. Of women diagnosed at ages 50-59 and 60-64 there is a 90 % five year survival (Office of National Statistics, 2012). Return to work figures after breast cancer vary significantly, influenced by psychosocial issues as well as physical issues. There are few quantitative studies, and none have specifically analysed return to physically demanding roles. Some studies have found 80 % returning to work (Fantoni et al., 2010, Hoving et al., 2009) but this is not often achieved, and physical problems as a result of surgery are likely to have a significant impact on many women attempting to return to operational firefighting. A study of low income women who were more likely to be working in manual roles found around 55 % returned to work (Blinder et al., 2012). Difficulty working with the arms raised is likely to be an issue for some, a problem more likely to be encountered following significant axillary surgery. In the absence of clear specific evidence it will be assumed that 50 % of firefighters treated for breast cancer will be fit to return to operational firefighting. Overall percentages are low, and there is no expected increase to age 60 and only a marginal expected increase to age 65.

7.4.9 Many cancers now have an excellent survival rate after treatment with expectation of a return to all normal activities including heavy manual work. There are few studies that looked at type of work, and although a general return of around 80 % can be expected, one review suggested this should be adjusted down by 20 % for physically demanding occupations (Amir and Brocky, 2009). Assuming that only 50 % will return to operational firefighting, this would suggest a doubling of ill health retirements for cancer from age 55 to 60 and a further doubling between age 60 and 64 for men. This in turn suggests that there will be around three retirements per thousand per annum for cancer in men aged 55-59, a doubling on the previous five years so around 1.5 per thousand per annum retirements would be expected in ages 55-59. For women there would be around 3.5 retirements per thousand per annum for cancer aged 55-59 but this is only an increase of around 20 %, with around 0.6 per thousand per annum increase on the previous five years.

7.4.10 The healthy worker effect could be significant in relation to cancer. Adipose tissue includes macrophages, and in obese individuals the macrophages are classically activated, producing adipokines which result in a permanent state of lowgrade inflammation. These adipokines, combined with increased levels of IGF1 from hepatocytes and increased levels of insulin, promote cellular proliferation and inhibit apoptosis. The result is an increase in solid tissue tumours. Altered levels of oestrogen resulting from adipose tissue may also contribute to breast and endometrial carcinoma. The result is that around 14 % of male cancer deaths and 20 % of female cancer deaths in USA can be attributed to being overweight or obese, with an increased risk of cancer in those with a BMI over 40 of 52 % (Calle et al., 2003). These figures are increasing, and it is thought they may represent a substantial underestimation of the effect of obesity, with diet having an additional substantial effect (Wolin et al., 2010).

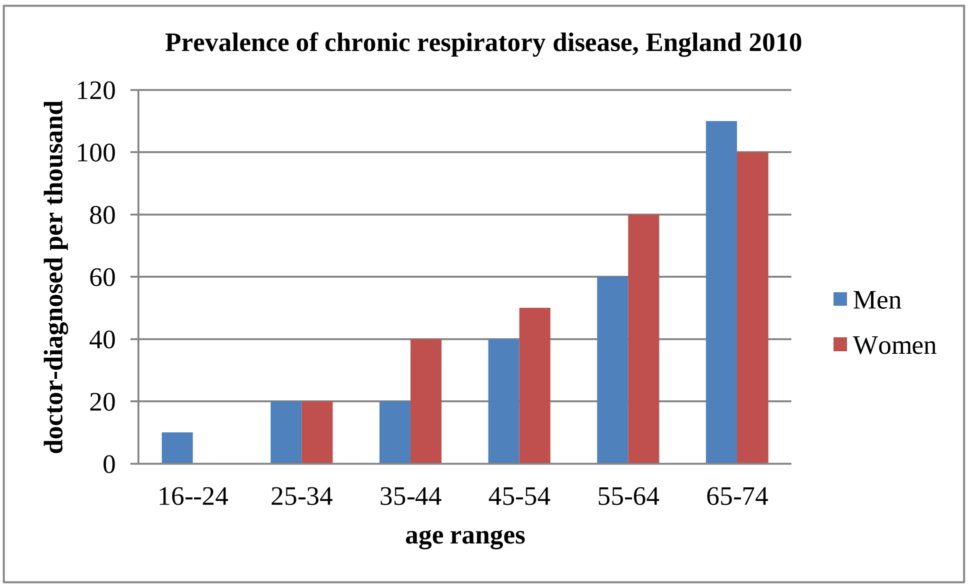
7.5 Respiratory disease

7.5.1 The two most common respiratory diseases are asthma and chronic obstructive pulmonary disease (COPD). Asthma does not vary substantially in prevalence from mid-life onwards, so an increase in retirement age is unlikely to see a significant increase in asthma among firefighters. COPD is predominantly a disease of older people, so an increase is likely. Furthermore, by definition a person with a diagnosis of COPD has reduced lung function, and is therefore likely to have problems maintaining fitness, achieving high fitness standards and coping with the operational demands of firefighting.

Table 7.10 Prevalence of doctor-diagnosed chronic bronchitis, emphysema and COPD per thousand population, England 2010 (Hall and Mindell, 2011)

	16-24	25-34	35-44	45-54	55-64	65-74
Men	10	20	20	40	60	110
Women	0	20	40	50	80	100

Figure 7.11 Prevalence of chronic respiratory disease, England 2010



7.5.2 Most of those diagnosed will find it difficult to achieve the fitness levels required for operational firefighting, and the data suggest around 55 per thousand of the population will have chronic respiratory disease in five year age band 50-54, increasing to around 70 per thousand at age 55-59.

7.5.3 There is evidence for an increase in respiratory problems related to specific firefighter exposure. Perhaps the best documented is the World Trade Centre response, where firefighters were not just exposed during the immediate disaster, but had long-term exposures during the clean-up operation. A large decline in forced expiratory volume (FEV_1) was noted over the first year, and the decline was persistent without recovery for the following six years suggesting this could be a permanent effect (Aldrich et al., 2010, Ekenga and Friedman-Jimenez, 2011).

7.5.4 The varied exposure of groups of firefighters is likely to make any statistical analysis very difficult, however the use of good personal protective equipment is expected to minimise the substantial risks. A recent review found some evidence for an increased risk of respiratory ill-health associated with firefighting but the research was inconclusive (Crawford and Graveling, 2012). Without any clear statistics for a relative risk, we have assumed that the risk to firefighters is the same as for the general population.

Table 7.11 Expected prevalence of firefighters unfit with respiratory problems at age groups 50-69. These figures are cumulative, not additive. If 55 per thousand retire up to age 54, only a further 15 per thousand would retire age 55-59

Age group	Total unfit per thousand firefighters
50-54	55
55-59	70
60-64	85
65-69	95

7.6 Musculoskeletal disorders

7.6.1 There is a steady rise in incidence and prevalence of musculoskeletal disorders with age. The common problems seen in the age range 45-65 include problems with the back, hip, shoulder and knee. A study carried out in three general practices in central England found, after adjusting for social deprivation, that the prevalence of musculoskeletal symptoms in the past month lasting for more than a week were 230 per 1000 back pain, 190 per thousand knee pain and 160 per thousand shoulder pain. The majority of subjects who reported pain had pain in more than one site and overall prevalence rose with age (Urwin et al., 1998). The detailed breakdown of conditions is seen in Tables 7.12 and 7.13.

Table 7.12 Prevalence of musculoskeletal symptoms in men per thousand in England 1998

	back	shoulder	hip	knee	any area
16-44	200	90	30	150	356
45-64	240	190	110	210	511
65-74	200	160	130	270	517

Figure 7.12 Prevalence of self-reported pain by site, men, central England 1998

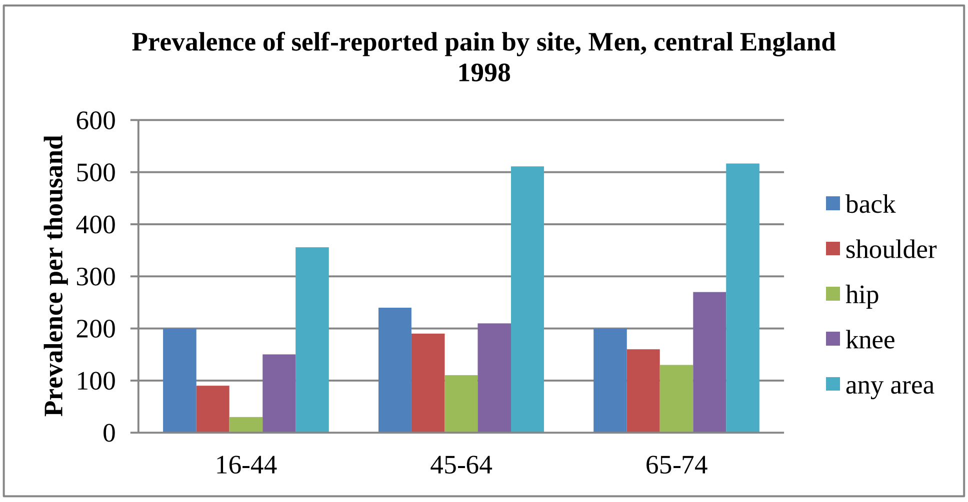
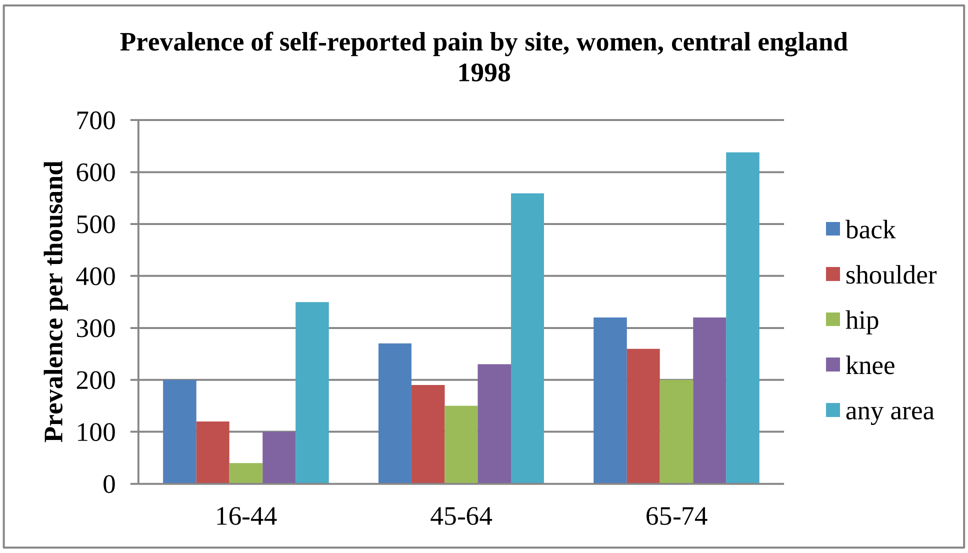


Table 7.13 Prevalence of musculoskeletal symptoms in women per thousand in England 1998

	back	shoulder	hip	knee	any area
16-44	200	120	40	100	350
45-64	270	190	150	230	559
65-74	320	260	200	320	638

Figure 7.13 Prevalence of self-reported pain by site, women, central England 1998



7.6.2 The significant points from this and other studies are that figures for back and shoulder problems in men show no major increases with age, peaking in middle age. This reflects the fact that most back and shoulder problems are self-limiting and relate to activity and posture rather than any significant underlying pathological changes. These findings do not apply to women who have a steady rise in symptoms with age. Hip and knee problems do show a steady increase with age in both sexes and are more likely to be related to underlying degenerative changes which correspondingly increase with age.

7.6.3 When considering the likelihood of ill health retirement, it is important to consider self-limiting conditions that should recover as well as conditions related to permanent degenerative change. Historically there have been high levels of ill health retirement due to conditions such as back pain which are usually not related to permanent degeneration but often appear to be permanent because of the associated maladaptive beliefs and behaviours. Ill health retirements continue for "simple" or "mechanical" back pain and unless the process of ill-health retirement becomes more evidence-based, retirements for simple back pain may rise with age.

7.6.4 Firefighters in UK are employed in both 'whole time' (full time) employment and 'retained' (reserve, as required) employment. Retained firefighters will usually have another job which may well be physically demanding. It is also accepted practice for some whole time firefighters to undertake other employment in addition to their firefighting role, an issue recognised in the Bain report (Bain et al., 2002). This represents a major confounder when considering the development of chronic musculoskeletal disorders in firefighters, as it is difficult to identify causation. Where ill health retirement results and an independent qualified medical practitioner (IQMP) has to determine whether there is a 'qualifying injury' this is usually a pragmatic decision where the firefighter is given the benefit of the doubt if there could be an association with firefighting. Statistics on qualifying injuries may therefore be unreliable when considering the aetiology of chronic musculoskeletal problems. Attempts to link development of chronic musculoskeletal problems with age are also confounded by other pressures, and it was well known that there was a substantial peak of ill-health retirements related mostly to musculoskeletal disorders once firefighters had served for 26.5 years due more to the pension system then in place than an increase in morbidity at that point (Ide, 1998). Any statistics in relation to ill-health retirement prior to the introduction of the IQMP in 2004 and the change in pension's regulations in 2007 must be viewed with this in mind.

7.6.5 Severe osteoarthritis (OA) is disabling and unless arthroplasty can successfully return the firefighter to full fitness, ill health retirement is likely. Osteoarthritis is a complex condition with multiple risk factors. There is clear evidence for genetic factors particularly for hip and knee arthritis. Biomechanical factors include a history of traumatic injury to the joint, destabilising the joint through injury or ligament laxity, malalignment, and occupational or recreational stress on the joint. Other factors include a higher incidence in women and a higher incidence particularly of knee OA with obesity. The relationship between knee OA and obesity is of major concern in the current 'epidemic' of obesity and appears to be due to immune mediators from fat tissue and disordered glucose and lipid metabolism as well as the increased loading on the knee (Sowers and Karvonen-Gutierrez, 2010). While progress of the disease and symptoms from the disease can be substantially altered by losing weight, once the OA is severe there is little that can be done to enable the individual to cope with active firefighting duties.

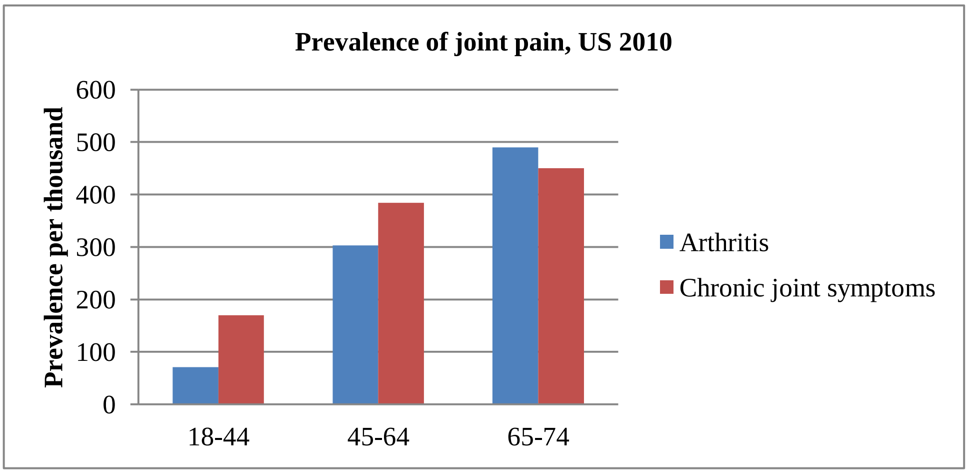
7.6.6 Osteoarthritis is not a condition with a clear start point. Prevalence estimates show wide variation and the point at which an individual becomes significantly impaired by their condition also varies substantially. It is therefore difficult to determine expected incidence and prevalence from the literature (Busija et al., 2010). General practice databases for consultation rates have in the past been considered useful sources for data on overall morbidity, however a study showed that recorded consultation rates for arthritis in general practice vary substantially between databases, so these do not necessarily provide an accurate source of data (Jordan et al., 2007). Prevalence of osteoarthritis also varies significantly even when using radiographic definitions suggesting high subjectivity when assessing radiographic evidence, and studies using a radiographic rather than clinical definition showed the highest prevalences (Pereira et al., 2011).

7.6.7 US figures are shown in Table 7.14 (Centers for Disease Control and Prevention, 2012).

Table 7.14 Prevalence of arthritis and chronic joint pain per thousand population, US 2010

	18-44	45-64	65-74
Arthritis	71	303	490
Chronic joint symptoms	170	384	450

Figure 7.14 Prevalence of joint pain, US, 2010

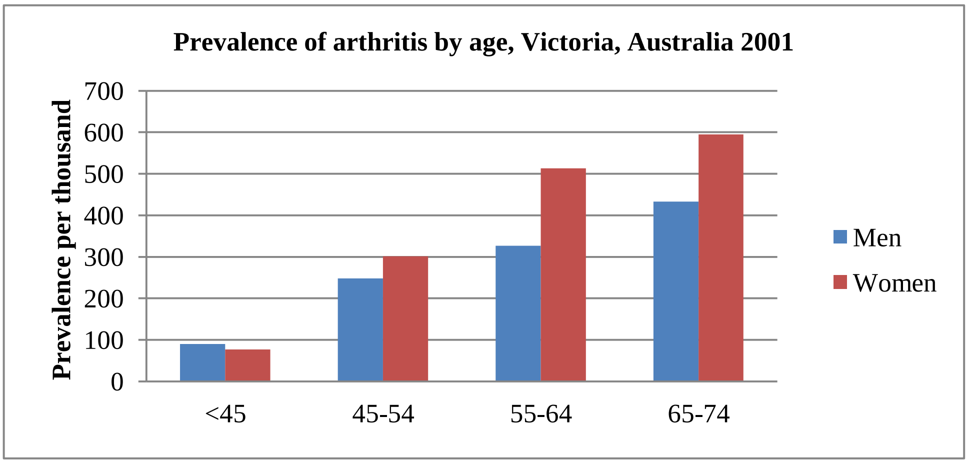


7.6.8 General statistics on arthritis are harder to find than for life-threatening diseases above. Where studies have considered age of onset or age-prevalence they commonly use wide groups such as under age, 45-65 and over-65. Such statistics are not of great help when looking at an increase in age of only five years. A study from Australia considered prevalence in decades.

Table 7.15 Prevalence of arthritis by age per thousand, Victoria, Australia 2001 (Busija et al., 2007)

	<45	45-54	55-64	65-74
Men	90	248	327	433
Women	77	301	513	595

Figure 7.15 Prevalence of arthritis by age, Victoria, Australia, 2001



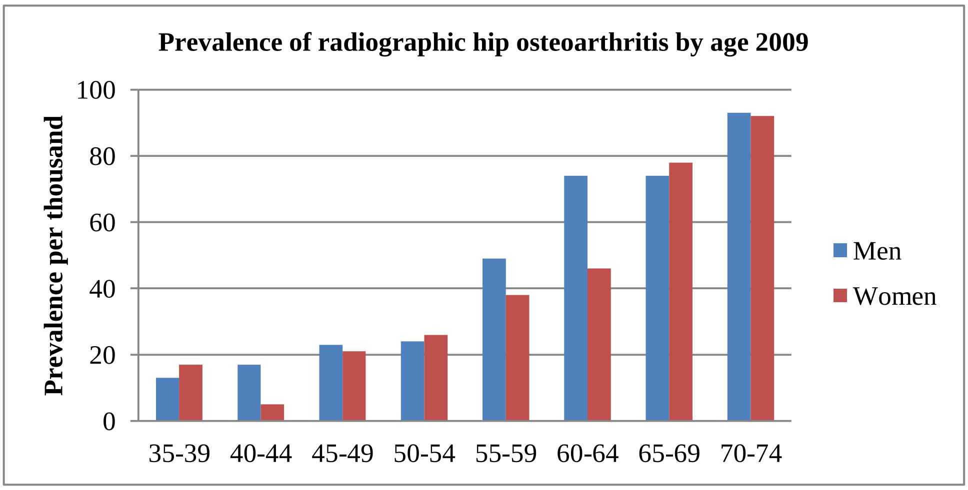
7.6.9 **Hip osteoarthritis**. There is no clear evidence that firefighters are at greater risk of developing osteoarthritis of the hip than the general public although two small studies suggest there may be a small increased risk (Crawford and Graveling, 2012). A Swedish study from 1991 identified an excess risk of hip osteoarthrosis in firefighters among other occupational groups (Vingard et al., 1991).

7.6.10 A review of the prevalence of radiographic primary hip osteoarthritis found a wide variation between studies (Dagenais et al., 2009), but the overall prevalence against age is shown in Table 7.16. Around half of those with radiographic osteoarthritis have significant symptoms (National Collaborating Centre for Chronic Conditions, 2008).

Table 7.16 Prevalence of radiographic hip osteoarthritis by age per thousand population, international, 2009

	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74
Men	13	17	23	24	49	74	74	93
Women	17	5	21	26	38	46	78	92

Figure 7.16 Prevalence of radiographic hip osteoarthritis by age per thousand 2009

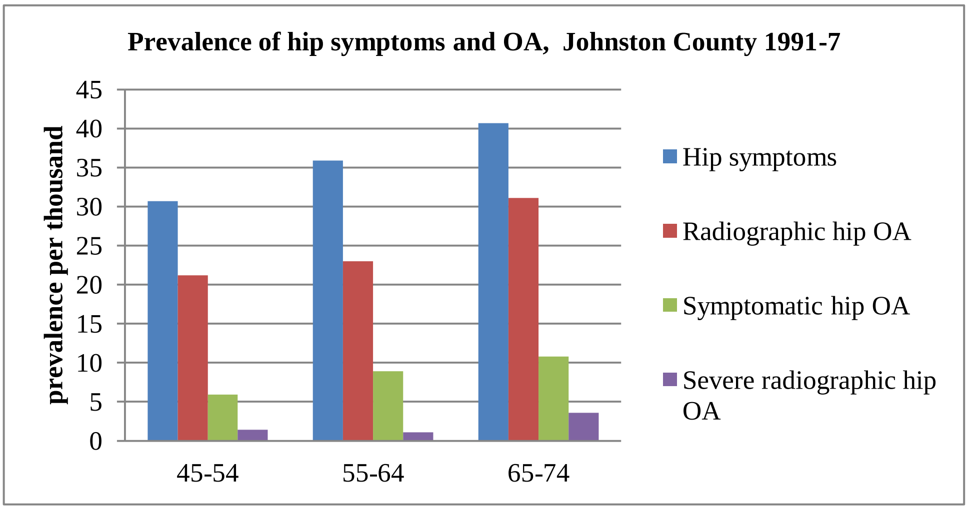


7.6.11 A study comparing hip symptoms, radiographic hip osteoarthritis, symptomatic hip osteoarthritis and severe radiographic hip OA showed the relationship between symptoms and severity of disease. This indicates that although symptoms are common, the prevalence of disease severe enough to limit function is substantially less (Jordan et al., 2009).

Table 7.17 Prevalence of hip symptoms and OA per thousand, Johnston County 1991-7

	45-54	55-64	65-74
Symptoms	307	359	407
Radiographic OA	212	230	311
Symptomatic OA	59	89	108
Severe radiographic OA	14	11	36

Figure 7.17 Prevalence of hip symptoms and OA, Johnston County 1991-7



7.6.12 For the purposes of this study, it will be assumed that the difference between men and women in the age range 50-59 is not significant. Half of those who have symptomatic hip OA will be unfit for firefighting. This does not mean permanently unfit, as there are several examples of firefighters who have successfully returned to operational firefighting following hip replacement surgery. They will, however, have a significant period where they are unavailable for operational duty, which may well amount to between six months and a year. It will be assumed that half those unfit will retire on ill health grounds. While it is difficult to get an accurate estimate of the increased risk with age, trend lines from the data above indicate a prevalence of severe radiographic hip osteoarthritis of 3.5 % aged 50-54. It is likely that there will be around a 2 % increase in the general population incapacitated by hip OA in the age group 55-59 compared to age 50-55.

Table 7.18 Expected prevalence per thousand firefighters of radiographic and symptomatic hip osteoarthritis and fitness. These figures are cumulative.

	total radiographic	total symptomatic	total unfit	total IHR
50-54	210	70	35	17.5
55-59	240	80	40	20
60-64	260	90	45	22.5
65-69	290	100	50	25

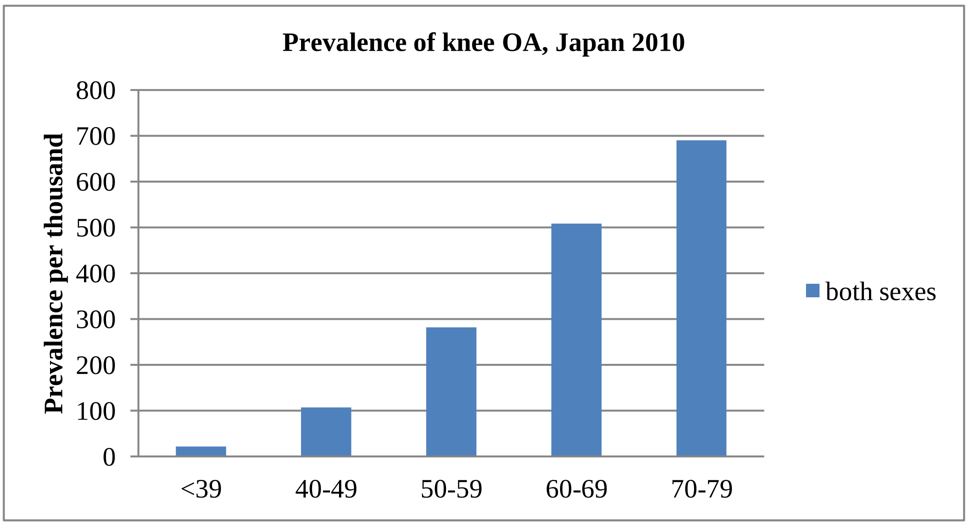
7.6.13 **Knee osteoarthritis**. Few studies break down prevalence of knee osteoarthritis into groups of working age. There are significant ethical constraints now in relation to X-ray studies of populations so many data sets are old. Many patients experience knee pain without underlying degenerative change but these symptoms generally resolve. Persistent symptoms of knee pain are associated with osteoarthritic changes with a clear link between severity, disability and radiographic changes (Duncan et al., 2007). Radiographic changes of osteoarthritis increase in prevalence with age, with evidence of significant OA for substantial numbers in the older population. Around half of adults over the age of 50 who have radiographic changes have symptoms (Peat et al., 2006).

7.6.14 A recent study from Japan found a significant rise in knee OA through working age, Table 7.19.

Table 7.19 Prevalence of X-ray evidence of knee osteoarthritis per thousand population in the ROAD study, Japan 2010 (Yoshimura et al., 2011)

	<39	40-49	50-59	60-69	70-79
both sexes	22	107	282	508	690

Figure 7.18 Prevalence of knee OA, Japan, 1010

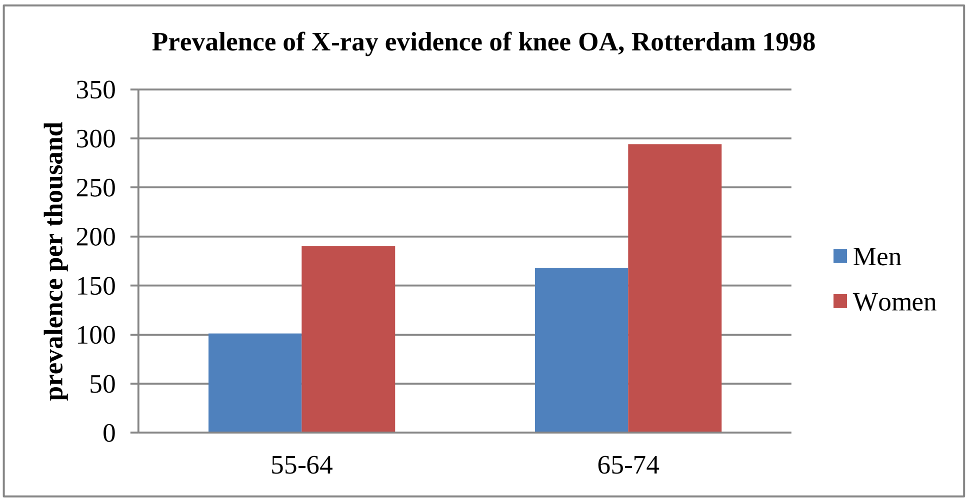


7.6.15 A study from Rotterdam in 1998 found similar increases but in older age groups, Table 7.20.

Table 7.20 Prevalence of X-ray evidence of knee osteoarthritis per thousand in Rotterdam, 1998 (Odding et al., 1998)

	55-64	65-74
Men	101	168
Women	190	294

Figure 7.19 Prevalence of X-ray evidence of knee OA, Rotterdam 1998

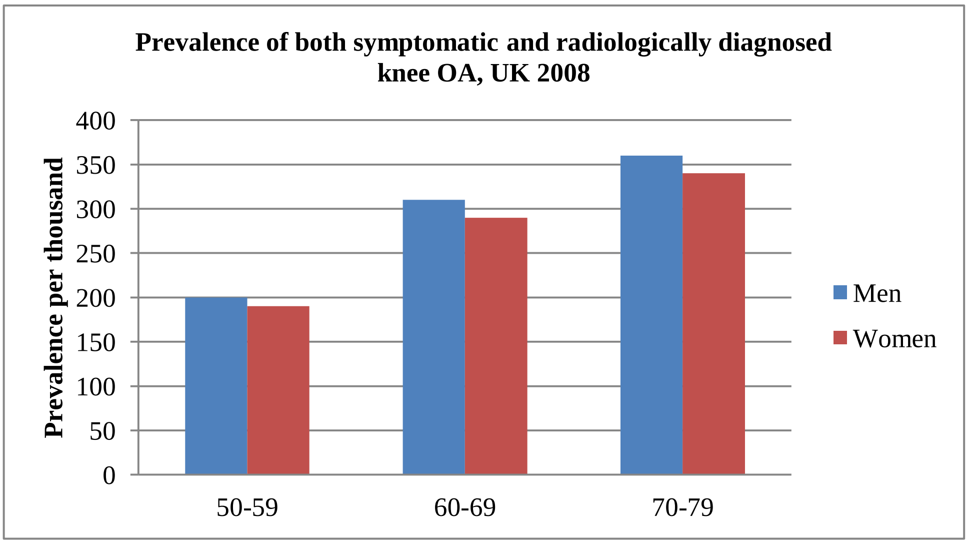


7.6.16 A UK study found significantly higher numbers of patients with both symptomatic and radiological evidence of knee OA (Peat et al., 2008).

Table 7.21 Prevalence of both symptomatic and radiological knee OA per thousand, UK 2008

	50-59	60-69	70-79
Men	200	310	360
Women	190	290	340

Figure 7.20 Prevalence of both symptomatic and radiologically diagnosed knee OA, UK 2008



7.6.17 The data above suggest that in the general population there will be an increase in symptomatic knee osteoarthritis from around 150 per thousand at age 50 to 200 per thousand at age 60. Symptoms are clearly common, and many firefighters with symptoms will remain capable of firefighting. It is not possible to estimate the numbers of firefighters likely to be permanently unfit because of knee osteoarthritis from these data. It is likely to be significantly greater than the numbers for hip osteoarthritis. The figures do, however, suggest a 25 % increase in those likely to be unfit between age range 50-54 and age range 55-59.

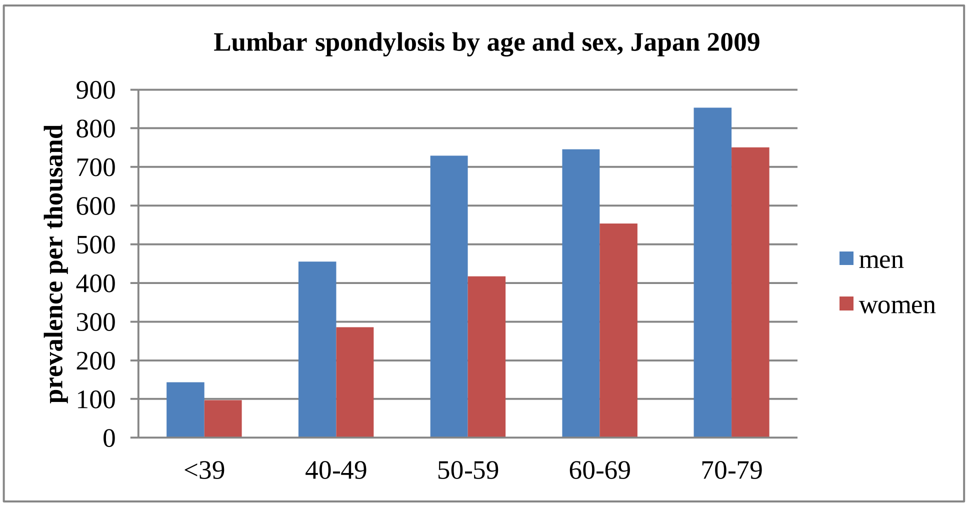
7.6.18 **Back degeneration**. Back pain is very common, and there are major psychosocial factors affecting the presentation, course and prognosis. It is important to distinguish between back pain unrelated to any significant underlying pathology and back pain or other symptoms related to permanent degenerative changes (Savigny et al., 2009). There is no evidence that employment as a firefighter leads to an increase in degenerative changes in the spine, as the amount of time spent undertaking heavy manual activity is relatively small. There is strong evidence against an association between back pain and most of the normal activities a firefighter would undertake (Kwon et al., 2011). A study of US urban firefighters found 80 % had reported neck, back or shoulder pain and this was negatively correlated with frequency of aerobic exercise (Beaton et al., 2002).

7.6.19 A study from Japan found substantial levels of lumbar spondylosis increasing with age, Table 7.22.

Table 7.22 Prevalence per thousand of lumbar spondylosis by age and sex, Japan 2009 (Yoshimura et al., 2009)

	<39	40-49	50-59	60-69	70-79
men	143	455	729	746	853
women	97	286	417	554	751

Figure 7.21 Lumbar spondylosis by age and sex, Japan 2009

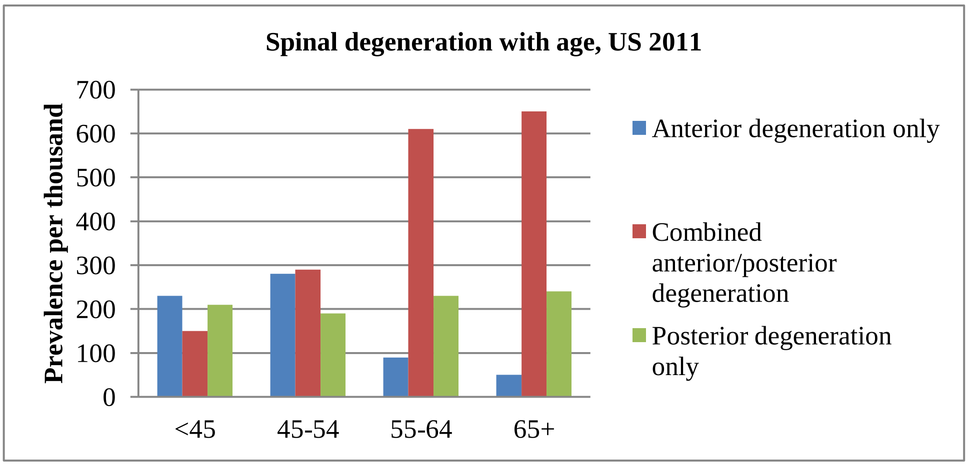


7.6.20 A study from US, with a total of only 361 participants also found substantial levels of lumbar spondylosis increasing with age, Table 7.23.

Table 7.23 Prevalence per thousand of spinal degeneration at various sites with age, US 2011 (Suri et al., 2011)

	<45	45-54	55-64	65+
Anterior degeneration only	230	280	90	50
Combined anterior/posterior degeneration	150	290	610	650
Posterior degeneration only	210	190	230	240

Figure 7.22 Spinal degeneration with age, US 2011



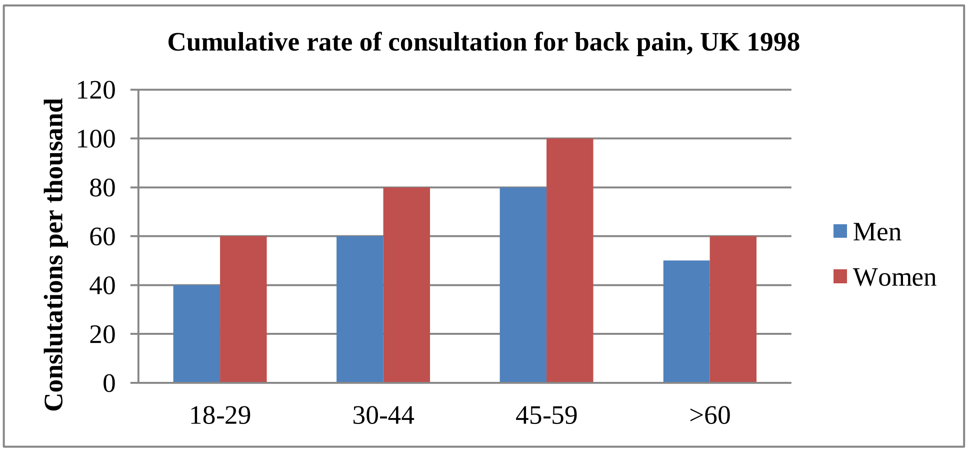
7.6.21 The evidence for a relationship between degenerative changes and symptoms is conflicting. Symptoms are very common, as are degenerative changes, but there is no absolute link between either of these and loss of function(Waddell, 2004). One study of current Olympic athletes found 83 % had altered disc signal, 81 % had some loss of disc height, and 58 % had disc displacement (bulge or herniation) (Ong et al., 2003).

7.6.22 Back pain is primarily a disorder of middle age, and consulting rates clearly demonstrate this, with a study from Manchester showing a peak before the age of 60. There is some evidence to suggest a link between degenerative changes and pain, but probably only from the onset of degenerative changes where inflammation may be present, indicated by Modic changes at the endplate (Kjaer et al., 2006). As degeneration progresses, pain settles and the individual resumes normal physical activity and no longer consults for back pain, Table 7.24.

Table 7.24 Cumulative rate of consultation for low back pain, per thousand, UK 1998 (Croft et al., 1998)

	18-29	30-44	45-59	>60
Men	40	60	80	50
Women	60	80	100	60

Figure 7.23 Rate of consultation for back pain, UK 1998



7.6.23 While back pain is unlikely to lead to permanent disability, significant pathology may affect future fitness for firefighting. Lumbar disc prolapse is often cited as a significant problem, however in many cases it is asymptomatic, and in cases where discectomy is needed a full recovery is expected with a return to normal activity (Dollinger et al., 2008). Few individuals fail to recover, and failure to recover is often linked to complex psychosocial issues. More significant problems are associated with more complex spinal surgery, particularly decompression and fusion for conditions such as spinal stenosis, which may be complicated by disc prolapse. While disc prolapse is generally considered to be a problem of early middle age, peaking in the early 40's, problems associated with spinal stenosis peak later. There are few large studies or reviews that give good epidemiological data. One study from Canada found a mean age of patients requiring spinal surgery for all conditions to be 57.4 (Cheng et al., 2010). Part of the Framingham study found absolute lumbar spinal stenosis (diameter 10mm or less) in 4 % of individuals younger than age 40 and 19.4 % of individuals aged 60-69 (Kalichman et al., 2009).

7.6.24 The evidence for treatment and disability related to spine disorders suggests that there would be no significant increase in incidence with an age increase from age 55 to 59 as the reduction in symptoms from spondylosis would be greater than the increase in symptoms from stenosis. Because back pain is so common, it can often become a surrogate reason for someone not coping, and this is not helped by inappropriate advice and treatment resulting from medicalization of the symptoms. The epidemiology of back pain does not therefore always follow the pattern expected from studies of pathological changes (Halligan and Aylward, 2006, Waddell et al., 2002, Waddell, 2004).

7.6.25 For firefighters in service, fewer over the age of 55 are expected to have significant episodes of disabling symptoms leading to sickness absence, so overall the expectation should be that there will be a positive impact on sickness absence. There will, however, be increasing numbers disabled by spinal stenosis, so overall the decline in those seeking ill health retirement with mechanical symptoms is expected to be matched by those with spinal stenosis and no significant change would be expected to age 60 with a gradual but small increase beyond this age. If very few firefighters are ill health retired with mechanical symptoms, then a steady increase will be expected from spinal stenosis.

7.6.26 **Shoulder pain**. Shoulder pain is less common than back or knee pain but more common than hip pain in the working population, and prevalence rates vary substantially between studies (Luime et al., 2004). A study of Australian nurses found a mean age for shoulder pain of 42.1 years (Hoe et al., 2012). Evidence from a Swedish general practice register found the mean age of problems to be around the age of 50 (Virta et al., 2012), see Table 7.25.

Table 7.25 Mean ages of shoulder symptoms in a Swedish general practice register 2012

	% distribution	mean age	median age	Male %	% required surgery
subacromial pain	89	48	51	49	48
stiffness	5	52	54	70	10
fracture	3	48	52	52	32
dislocation	3	51	55	55	10

7.6.27 The evidence suggests that there would be no significant increase in incidence from age 55 to 60 and beyond.

7.7 Mental ill-health

7.7.1 Mental disorders are common, and firefighters are as susceptible as the rest of the population. The most common mental disorders are those of affect or mood (mostly depression and anxiety). They arise on a spectrum; it is entirely normal to experience quite profound short-lived feelings of depression and anxiety as a result of circumstances, and we generally develop coping mechanisms to enable us to deal with these feelings appropriately. The great majority of people who experience depression do so as a result of circumstance and in the great majority of these cases the best approach is to continue with normal activities; this helps restore a sense of perspective, interaction with others helps provide the supportive environment that is the best treatment, and the combination of support and internal coping mechanisms is generally all that is needed for a full recovery within a short period of time. Such events and experiences used not to be considered particularly abnormal, and were never medicalised. The development of antidepressant medications has resulted in substantial medicalisation of these symptoms, often with the expectation that doctors will make the patient better rather than allowing the development of natural coping mechanisms. The result is that when reviewing data it can be difficult to separate out those few people with substantial enduring depressive illnesses and persisting anxiety who need ill health retirement from those who are simply reacting to events or whose recurrent depression will be short-lived and who can return to firefighting once recovered.

7.7.2 The term ‘common mental disorders’ includes depression, anxiety, mixed anxiety and depression, phobia, obsessive compulsive disorder and panic disorder. The separation into these terms is an artificial construct necessary for psychiatric diagnosis and treatment; in practice patients often cross boundaries with a mix of symptoms. When assessing fitness for work it is often better to focus on coping mechanisms rather than diagnosis. Provided the patient can cope with work, and is safe to work as a firefighter, the actual diagnosis is less relevant. It is therefore reasonable to group these together as a whole and consider those who require treatment as unlikely to be fully fit for firefighting while being assessed and starting treatment, assuming treatment follows recommended guidelines (National Collaborating Centre for Mental Health, 2009). In practice, treatment is often offered to those with symptoms that are not substantial enough to meet evidence-based guidelines for treatment (Macdonald et al., 2009).

7.7.3 The expectation for common mental disorders is for a full recovery and a return to work. Very few who have been successfully recruited to the fire service will be unable to continue to serve in spite of occasional episodes of depression and anxiety. The incidence of common mental disorders among firefighters is likely to reflect that in the general population, but the numbers permanently unfit for firefighting should be small. Most importantly, the common mental disorders do not usually affect insight or cognition. Mental disorders likely to have a more enduring effect on employability are those that affect personal interactions, insight or cognition. These are the personality disorders and psychoses. It can be much harder to function effectively in an emergency role where safety-critical decisions can affect the lives of the firefighter, their fellow firefighters and the members of the public they are serving with a psychotic illness or significant personality disorder, even one that is well treated. Many firefighters diagnosed with these disorders are likely to need to leave on ill health retirement although the absolute numbers are likely to be very small.

7.7.4 Another disorder likely to be seen within a firefighting population is post-traumatic stress disorder (PTSD), a disorder where the acute effects can prevent effective firefighting for periods of time but a good recovery can be expected with a return to active duty. The great majority of firefighters developing PTSD should recover and be able to return to active firefighting.

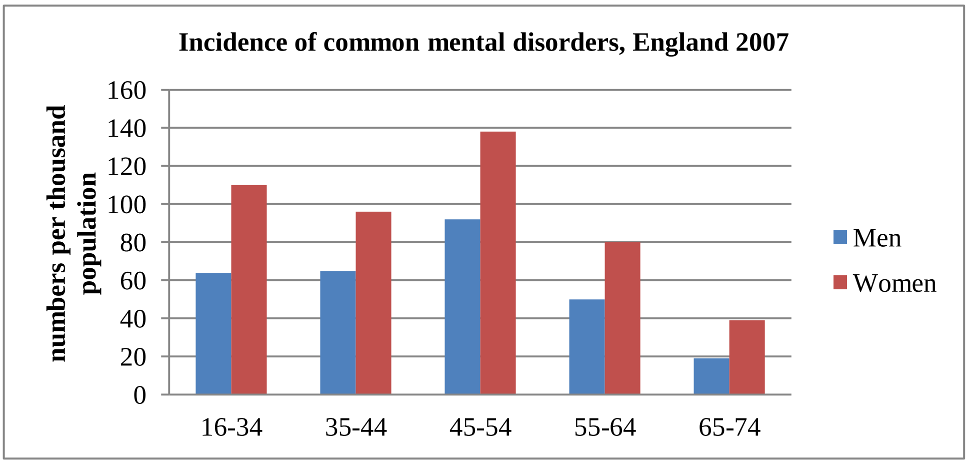
7.7.5 Substance abuse is very common within the general population, and the acute effects will prevent effective firefighting. The success rate for recovery from substance abuse is generally good but the threshold for accepting recovery has to be high because of the safety-critical role of firefighters.

7.7.6 **Common mental disorders**. A survey of adults in England asking about symptoms of common mental disorders over the past week used the revised Clinical Interview Schedule, where a score of less than 12 indicated no clinically significant neurotic symptoms in the week prior to interview. Most adults (84.9 %) scored less than 12, and half scoring more than 12 scored 12-17 indicating significant neurotic symptoms unlikely to warrant treatment, leaving 7.6 % of adults with symptoms that warranted treatment (NHS Information Centre, 2009). This latter group is likely to represent those who were likely to be unfit for firefighting while they were being diagnosed and started treatment.

Table 7.26 Incidence of significant symptoms of common mental disorders, per thousand, England 2007, by age and sex

	16-34	35-44	45-54	55-64	65-74
Men	64	65	92	50	19
Women	110	96	138	80	39

Figure 7.24 Incidence of common mental disorders warranting treatment per thousand population, England 2007

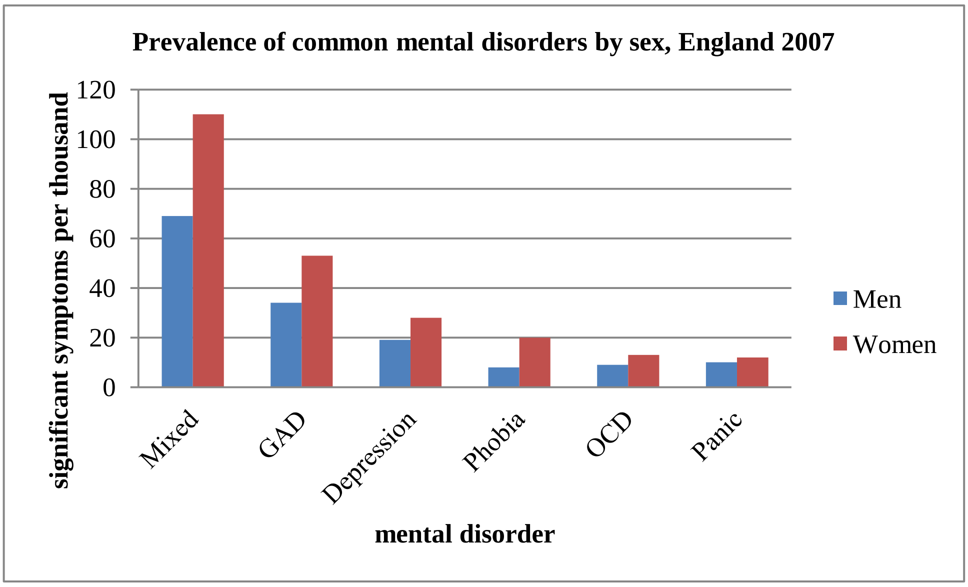


7.7.7 Common mental health disorders can be separated into specific diagnostic categories.

Table 7.27 Prevalence per thousand of each common mental disorder by sex, England, 2007

	Mixed anxiety & depression	Generalised anxiety disorder	Depression	Phobia	Obsessive compulsive disorder	Panic disorder
Men	69	34	19	8	9	10
Women	110	53	28	20	13	12

Figure 7.25 Prevalence of common mental disorders by sex, England 2007



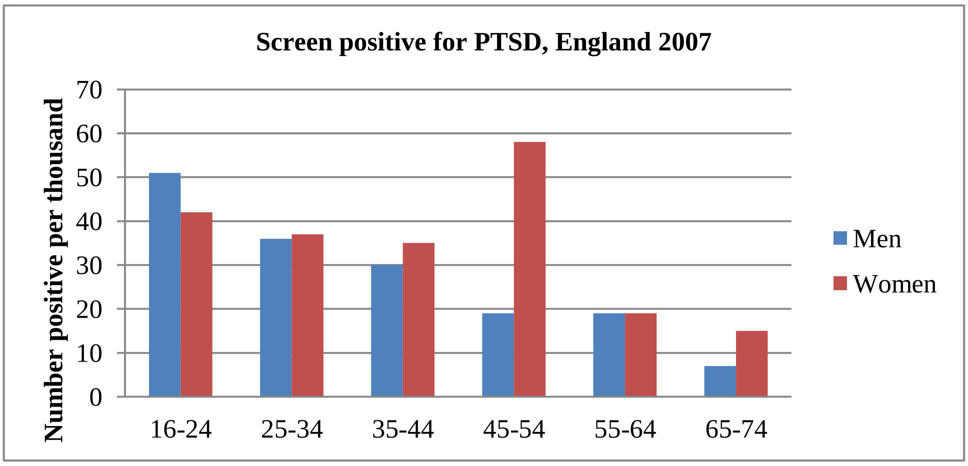
7.7.8 The data in Fig 7.24 above show the decline in significant symptoms with age from age range 45-54, clearly reflecting the development of coping strategies over time. Firefighters will also, through the process of selection and training, develop coping strategies which would be expected to further reduce the incidence and prevalence of common mental disorders. These data suggest that older firefighters will be better able to cope with symptoms of depression and anxiety and are less likely to go off sick or be retired on health grounds.

7.7.9 **Posttraumatic stress disorder (PTSD).** Posttraumatic stress reactions are normal, but generally settle quickly as coping strategies are developed. PTSD is a specific disorder that develops in some individuals after trauma, sometimes many years after trauma. While only around a third of the population have been exposed to a case-defining traumatic event, most firefighters will have been exposed to at least one, as that is the nature of their role. PTSD is disabling and a firefighter having significant symptoms may not be fully effective and safe in an operational role. Recovery is expected in the great majority and most firefighters who develop the condition are expected to return to full operational capability. Diagnosis is complex, so any screening study cannot hope to have a high level of specificity. The 2007 survey in England was the first to provide general prevalence estimates from a large population sample in UK (NHS Information Centre, 2009).

Table 7.28 Numbers screening positive for PTSD per thousand, England 2007

	16-24	25-34	35-44	45-54	55-64	65-74
Men	51	36	30	19	19	7
Women	42	37	35	58	19	15

Figure 7.26 Numbers screening positive for PTSD per thousand, England 2007



7.7.10 These results are not necessarily directly applicable to firefighters. Screening positive required exposure to trauma since age 16, however in many cases the exposure is in early life, so a reduction in prevalence would be expected with age. Firefighters are potentially exposed throughout their career, however all studies showed a moderating effect of increased age on prevalence of PTSD. The significant peak for women aged 45-54 reflects a higher incidence and prevalence of all mental health symptoms and illnesses found in the survey in this age group.

7.7.11 Comparing PTSD prevalence internationally is potentially challenging, as PTSD rates vary significantly; cultural factors play a substantial role in the development of the disorder and response to it. The nature of the trauma and degree of exposure will be relevant. Good data have come from studies of the World Trade Center Disaster, and a prevalence rate of probable PTSD was 7.4 % among WTC-exposed firefighters in September 2010 (Soo et al., 2011). A study of US combat veterans found that although the oldest group of veterans had the highest combat exposure, a prevalence of PTSD of 6.3 % in over-65s compared to 18.6 % in those aged 45-64 (Frueh et al., 2007).

7.7.12 Overall there is no good evidence to suggest an increase in PTSD with age, and significant evidence to suggest it will reduce with age.

7.7.13 **Alcohol and drugs**. Alcohol consumption is a major issue and dependence can substantially affect safety and performance for firefighting. It varies substantially with age, sex and location. Figures are taken from the Annual Psychiatric Morbidity Survey for England 2007 (NHS Information Centre, 2009).

Table 7.29 Alcohol dependence per thousand in past six months by age and sex, England 2007

	16-24	25-34	35-44	45-54	55-64	65-74
Men	126	168	96	61	50	30
Women	98	30	37	35	9	6

Figure 7.27 Alcohol dependence per thousand in past six months by age and sex, England 2007

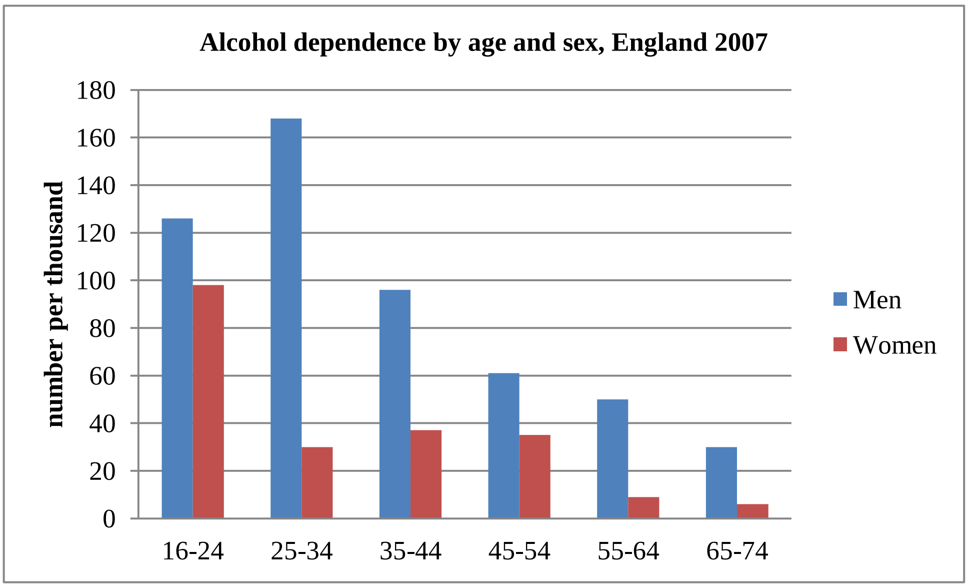
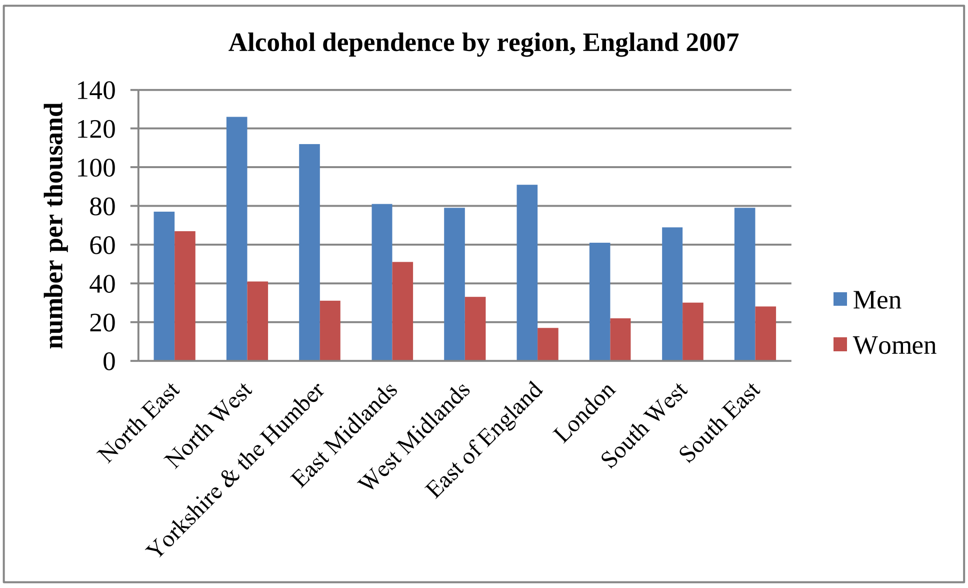


Table 7.30 Alcohol dependence per thousand in past six months by region, England 2007

	North East	North West	Yorkshire & the Humber	East Midlands	West Midlands	East of England	London	South West	South East
Men	77	126	112	81	79	91	61	69	79
Women	67	41	31	51	33	17	22	30	28

Figure 7.28 Alcohol dependence per thousand in past six months by region, England 2007



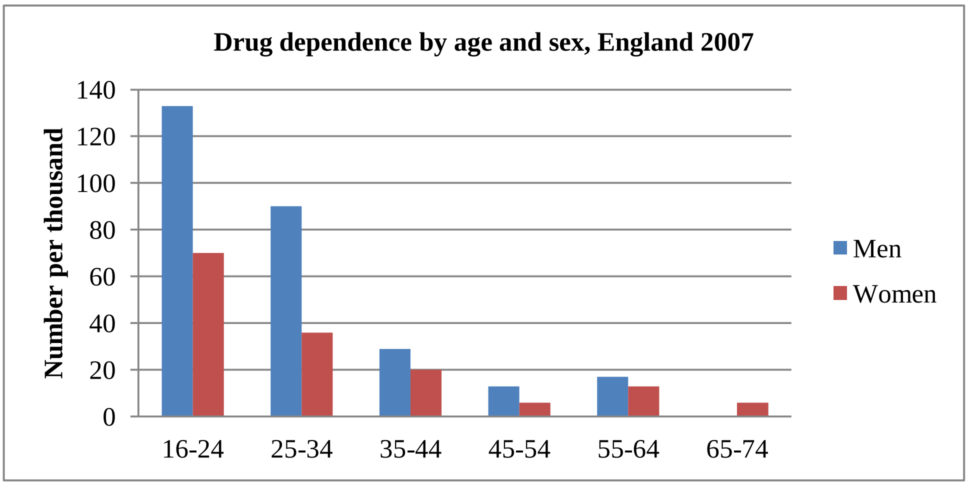
7.7.14 The data shown above indicate the potential challenges for all Fire and Rescue Services. Alcohol dependence is endemic, and the problem varies substantially across the UK. It is a problem mostly for young firefighters; it is not a significant issue in relation to an increase in pension age and is not expected to lead to significant numbers ill health retired.

7.7.15 Drug dependence is as prevalent in the younger age group but tails off much more in middle age, with low prevalence around pension age.

Table 7.31 Drug dependence per thousand in past six months by age and sex, England 2007

	16-24	25-34	35-44	45-54	55-64	65-74
Men	133	90	29	13	17	0
Women	70	36	20	6	13	6

Figure 7.29 Drug dependence per thousand in past six months by age and sex, England 2007



7.7.16 Overall the data suggest that drug dependency is not a significant issue in relation to an increase in pension age.

7.8 Summary of the expected effects of health on the ability of firefighters to serve beyond age 55

7.8.1 A mortality rate of around 7 per thousand per annum is expected for men firefighters aged 55-59 and 3.2 per thousand for women firefighters per annum.

7.8.2 Heart disease is expected to lead to around 5 per 1000 men retiring per annum age 55-59, an increase of around 3 per 1000 in age group 50-54. For women it is expected to lead to around one per 1000 retiring per annum age 55-59, an insignificant increase from age group 50-54.

7.8.3 Stroke expected to lead to around 1 per 1000 men retiring per annum age 55-60, an insignificant increase from age group 50-55. For women it is expected to lead to around one per 1000 retiring per annum, an insignificant increase from age group 50-55.

7.8.4 Cancers are expected to lead to around 0.6 per 1000 men retiring per annum age 55-59, an increase of around 0.3 per 1000 in age group 50-54. For women it is expected to lead to around 0.3 per 1000 retiring per annum, no increase from age group 50-55.

7.8.5 Respiratory diseases are expected to lead to around 3 per 1000 firefighters retiring per annum age 55-59, an insignificant increase from age group 50-54.

7.8.6 Hip osteoarthritis is expected to lead to around 0.5 per 1000 firefighters retiring per annum age 55-59, an insignificant increase from age group 50-54.

7.8.7 Knee osteoarthritis expected to lead to more ill health retirements than hip osteoarthritis but the rate cannot be estimated from population statistics. The available statistics suggest an increase of 25% between age group 50-54 and age group 55-59.

7.8.8 Back problems are not expected to lead to any significant change in ill health retirements between age groups 50-54 and 55-59.

7.8.9 Shoulder problems are not expected to lead to any significant change in ill health retirements between age groups 50-54 and 55-59.

7.8.10 Common mental disorders are not expected to lead to any significant change in ill health retirements between age groups 50-54 and 55-59.

7.8.11 PTSD is not expected to lead to any significant change in ill health retirements between age groups 50-54 and 55-59.

7.8.12 Alcohol and drug abuse is not expected to lead to any significant change in ill health retirements between age groups 50-54 and 55-59.

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8 Shiftwork and age

Anthony N Williams

8.1 Introduction

8.1.1 Humans are diurnal and naturally sleep at night. Working different shift patterns during the day is only relatively disruptive, but working night shifts alters the sleep-wake cycle and can have a significant effect on performance and health. These effects are well documented (Smith et al., 1998, Harma and Ilmarinen, 1999). The issue of concern for this review is the effect of age on this complex process.

8.1.2 There are a number of conditions that substantially affect sleep, for example obstructive sleep apnoea (OSA), pain, urological conditions leading to increased frequency at night and psychological problems. OSA is predominantly a condition of obesity, and would therefore be a significant issue for older firefighters only if there were a substantial increase in obesity above the age of 55. Pain will be associated with other medical conditions which, along with common mental health problems are considered in Chapter 7.

8.1.3 As people age there is a circadian shift, with an increase in ‘morningness’ associated with greater difficulty sleeping and a tendency to be sleepy in the mid to late afternoon. Some of the performance reduction seen with shiftwork was associated with less fit older workers, while fit older workers performed better than unfit younger workers (Reilly et al., 1997). This circadian shift could arguably lead to a decrease in performance in the afternoon but a possible increase in performance at the start of the day. These results were also found in a Japanese study of policemen, where older shiftworkers also reported higher ‘morningness’ and lower sleep need than younger shiftworkers, and although the study suggested that age can be linked to depleted shiftwork tolerance this was not proven (Smith and Mason, 2001).

8.1.4 A review of the impact of aging concluded that older workers over the age of 40 obtained consistently less sleep than younger workers, there is a clear increased risk of heart disease among shiftworkers and an increase in gastrointestinal symptoms, but these increases are progressive with age with no significant shift in effect above a specific age or duration of shiftwork. Many of the risks are due more to the lifestyles associated with shiftwork than shiftwork itself, and shiftworkers can also adapt to cope with the lifestyle changes. There is also evidence that the positive effect of experience counters the negative effect of fatigue. The review emphasised the need to intervene to ensure sufficient daily sleep, and ensure there were sufficient breaks during the work shift (Harma and Ilmarinen, 1999). There is no indication from this review for any substantial increase in risk of fatigue, heart disease or gastrointestinal problems between age range 50-54 and age range 55-59.

8.1.5 Physical fitness in older workers appears to have an effect on shiftwork largely because of the impact it has on sleep quality and fatigue rather than physical performance at work. Shiftworkers undertaking moderate physical training have increased sleep length and night-time alertness (Harma, 1996). Some of the apparent effects of shiftwork on older workers may therefore relate to lower physical fitness with age rather than age itself. An earlier study looking at shiftwork tolerance in women found neuroticism to be the most powerful negative factor causing higher fatigue, with high VO_2max and good muscle strength being the most important positive factors connected to lower fatigue and better sleep quality (Harma et al., 1988).

8.1.6 A large French study into aging, health and work (the VISAT study) identified changes in cognitive ability with shiftwork, in particular that cognitive functioning tends to be impaired by long-term exposure to shiftwork (Rouch et al., 2005). This has also been suggested by other studies, but at present there is no clear objective test to clarify the size and significance of this effect (Dodman et al., 2012).

8.1.7 A study looking at work ability using the Work Ability Index (WAI) found a decline with age, however the WAI is self-reported and there was no objective measure to confirm any decline or to attribute a degree of decline or risk associated with it. Although a reduction in WAI was noted for men over the age of 55 doing shiftwork attributed to chronic fatigue and sleep problems, this was not statistically significant (Costa and Sartori, 2007).

8.1.8 There is a known association between shiftwork and metabolic syndrome, thought to be mediated by a combination of lifestyle factors including exercise and diet, along with altered secretion of cytokines involved in insulin resistance and cardiovascular disease (Crispim et al., 2012, Tucker et al., 2012). An increased prevalence of metabolic syndrome with age will result in increased problems related to shiftwork.

8.1.9 A study of policemen in Germany found an increase in risk of reduced fitness for duty with increasing number of years in shiftwork, in particular beyond 20 years of shiftwork (Wirtz and Nachreiner, 2012).

8.1.10 A study of healthcare workers in Italy, mostly women, found significant health effects related to shiftwork, and poorer health with age, but no clear interactions between the two (Conway et al., 2008). A study of Australian rural paramedic shiftworkers also found higher risk for fatigue and depression but no significant association with age and gender (Courtney et al., 2012). A study of nurses in Australia found younger nurses were most fatigued by shiftwork, but the effect of age was equivocal because of confounders including slightly different shift patterns and responsibilities and a well-adapted ‘survivor cohort’ (Winwood et al., 2006).

8.1.11 A study of Swedish shiftworkers found no increase in mortality between shiftworkers and day workers. There was an association between an increased risk of coronary heart disease and shiftworkers with shiftworkers who had greater than thirty years of shiftwork having the highest risk, a standardised relative rate of 1.24. Diabetes was more common, and the risk of stroke was greater in shiftworkers (Karlsson et al., 2005). This could be explained in part by the increased risk of metabolic syndrome in shiftworkers.

8.1.12 A major review of the possible effect of shiftwork on cancer concluded that shiftwork that involves circadian disruption is probably carcinogenic to humans but there was only limited evidence and the effect could not be quantified (IARC, 2010).

8.1.13 Firefighter shifts do not necessarily have to have similar shifts to production workers who will need to be fully alert and productive throughout the shift. The Grey Book provides for a period of stand down, although that does not necessarily mean firefighters are allowed to sleep, and the ability to require staff to work wakeful shifts was a core part of the 2004 pay agreement. If firefighters are required to remain awake throughout every night shift worked this could have a significant impact compared to a situation where there might be no absolute requirement for firefighters to be 'busy' throughout a night shift.

8.1.14 While there is a clear issue of tolerance of shiftwork, most people who cannot tolerate shiftwork change jobs when young, leaving a group who appear more tolerant, and who have made the necessary lifestyle adaptations to cope. Those who continue to undertake shiftwork do appear to have some significant risks, partly related to lifestyle associated with shiftwork and partly related to the underlying physiological disturbances of the circadian rhythm. It is likely that there will be an increased risk the longer workers continue to do shiftwork. Many authors suggest reducing or limiting shiftwork for older workers not because of any clear objective measured effect, but simply because it seems to make sense. Where adjustments can be made to limit shiftwork exposure for the older worker these will undoubtedly have a beneficial effect. There is no clear statistically demonstrable 'cut-off age' after which shiftwork must be avoided.

8.1.15 In summary, there is only limited evidence to show that firefighters in the age group 55-60 would be less tolerant of shiftwork, or exposed to greater health risks, than those aged 50-55. Most studies are equivocal or show no clear and direct association. There is some evidence to show that maintaining physical fitness and muscle strength will help improve shiftwork tolerance in older firefighters. It is for management to determine the best shift system to operate considering all the general evidence around shiftwork and performance, and factors operating locally.

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9 Leaving for medical reasons

Anthony N Williams

9.1 Introduction

9.1.1 Some firefighters reach a point in their career when they can no longer cope with the role. Where this is for medical reasons, it is important to assess the underlying condition and determine whether their inability to cope with the role is likely to be permanent because of the condition even after appropriate treatment has concluded. In a small number of cases they will be found to be permanently incapable of firefighting and ill health retirement (IHR) will be recommended. In a few cases the firefighter may feel capable of continuing but the risks associated with an underlying condition may be too great to accept, and ill health retirement will be recommended in these cases too. Unlike a simple capability dismissal, when a firefighter leaves on IHR their pension is paid from the date of leaving rather than from normal pension age, at significant cost to the pension scheme.

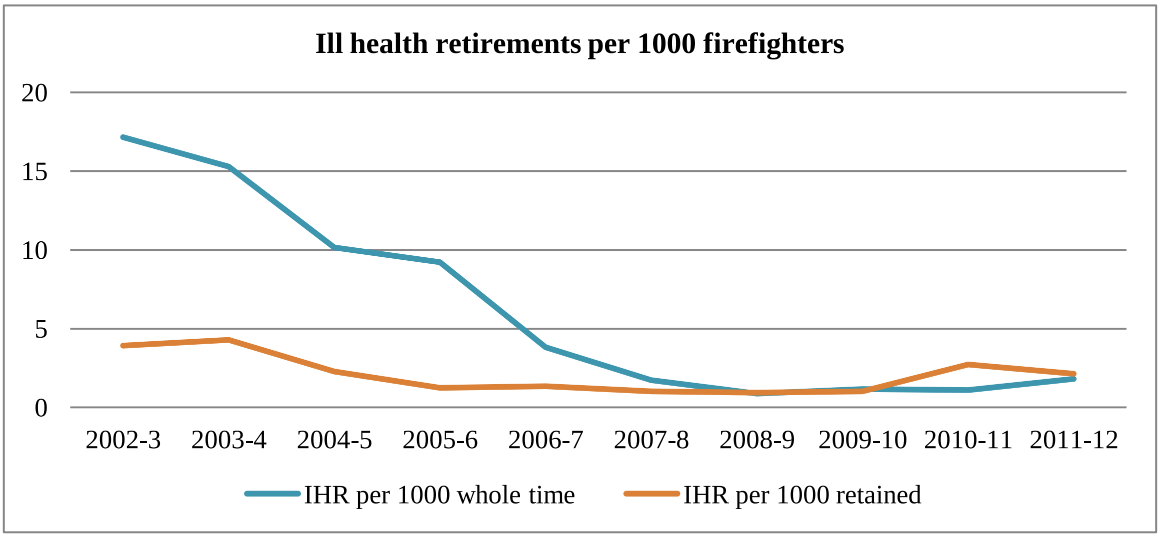
9.1.2 While it is clearly appropriate that this process is in place to support those who need it, it is important to consider the way it is applied. It usually starts because a firefighter is no longer able to cope with the role. Not all firefighters meet the criteria, so significant numbers will be in a position where they can no longer cope, often through loss of fitness, but the only option is to leave or have their contract terminated on capability grounds without early payment of pension. This is often a difficult process for all involved. It can be a sad, negative way to end a long career with the fire service; it can take many months and may involve disciplinary issues, and often involves a lot of time and effort. If considered purely in economic terms it is not an efficient and effective way to end a career. It can cause a lot of distress for the firefighter, for colleagues and for management.

9.1.3 It is reasonable to use IHR occasionally and where appropriate. It is not reasonable to have to use it regularly because a substantial proportion of firefighters nearing retirement age are no longer medically capable of working in their role unless the pension scheme is designed to support high levels of IHR. Where firefighters have become physically unfit they will often have medical symptoms associated with this, so in most cases of capability dismissal the process of IHR will be included even if the firefighter does not eventually meet the criteria. In the past IHR was used frequently and significant concern has been expressed about the inappropriate use of IHR (Bain et al., 2002). This was found to be economically unsustainable as well as entirely inappropriate, and the process for IHR was changed in 2004 to make it more robust and objective (see Figure 9.1 below). It is important to avoid a situation where this becomes the normal route out at the end of a firefighting career.

9.2 Ill health retirement rates.

9.2.1 Ill health retirement is likely to become more common, and applications for IHR much more common, if a substantial percentage of firefighters either develop serious chronic disease or become physically unfit for operational duty. Likely rates of chronic disease have already been considered above. This review has included a study to review numbers and reasons for IHRover the past five years. Prior to this the process was too subjective (Bain et al., 2002, Ide, 1998) to provide useful data as can also be seen in the graph below.

Figure 9.1 Rates of ill health retirement per 1000 firefighters over the past 10 years



9.3 Ill health retirement rates for the past five years

9.3.1 The figures for the past five years show a steady rate of IHR at around 1/1000 serving firefighters. Once the process was made more objective, the rate for whole time firefighters came down to the same level as that for retained firefighters who have also now been included in the pension scheme suggesting that this is likely to be based on medical factors rather than non-medical issues.

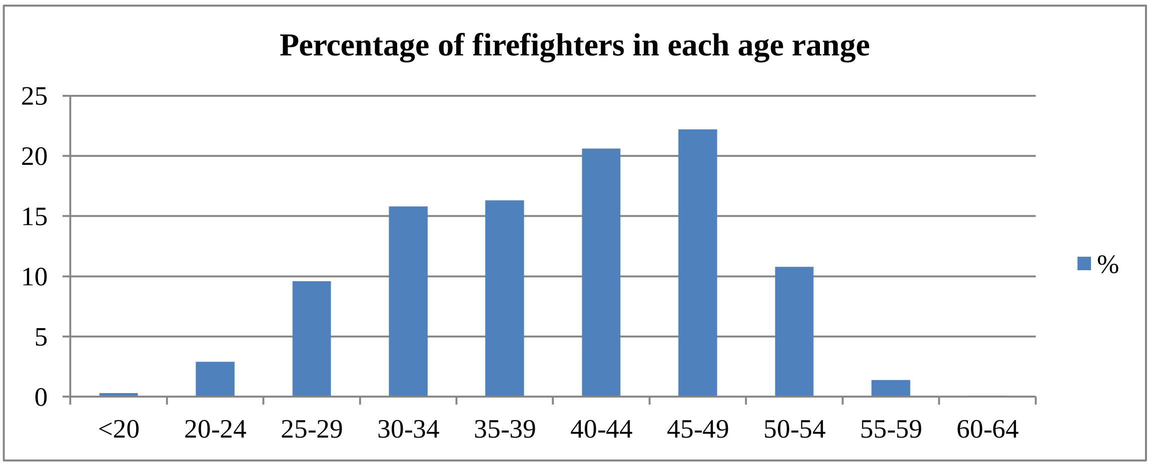
9.3.2 Fire Services in UK and Northern Ireland were asked to provide data for IHR for the years March 2007 to March 2012 including age, sex, whether whole time or retained, and reason for ill health retirement. A mean value of firefighter numbers in post was calculated for the five years and IHR totalled for the five years. The years were combined partly to produce more statistical power, and partly to help anonymise data in accordance with the ethical requirements.

9.3.3 Out of a total of 57 services, five were unable to provide any statistics, and a further 14 were unable to provide full details; in most cases the reason for IHR was not available. This left 38 services, with a denominator of 41,406 firefighters. There were a total of 333 ill health retirements in the five years, a rate per annum per 1000 firefighters of 1.6. Only four of these were women, with a denominator of 1,126, a rate per annum of 0.7 although this figure has little statistical significance. In order to ensure anonymity for the women, their results have been combined with the results for men. There were a total of 233 IHR for wholetime firefighters with a denominator of 28,600, a rate per annum per 1000 of 1.63. There were a total of 100 IHR for retained firefighters with a denominator of 12,806, a rate per annum per

1000 of 1.56. Chi square analysis gives a P value of 0.76, suggesting that there is no significant difference between whole time and retained firefighters.

9.3.4 Firefighter numbers are not uniformly distributed across all age ranges. Complete data on ages was available from five FRSs. The results are show below:

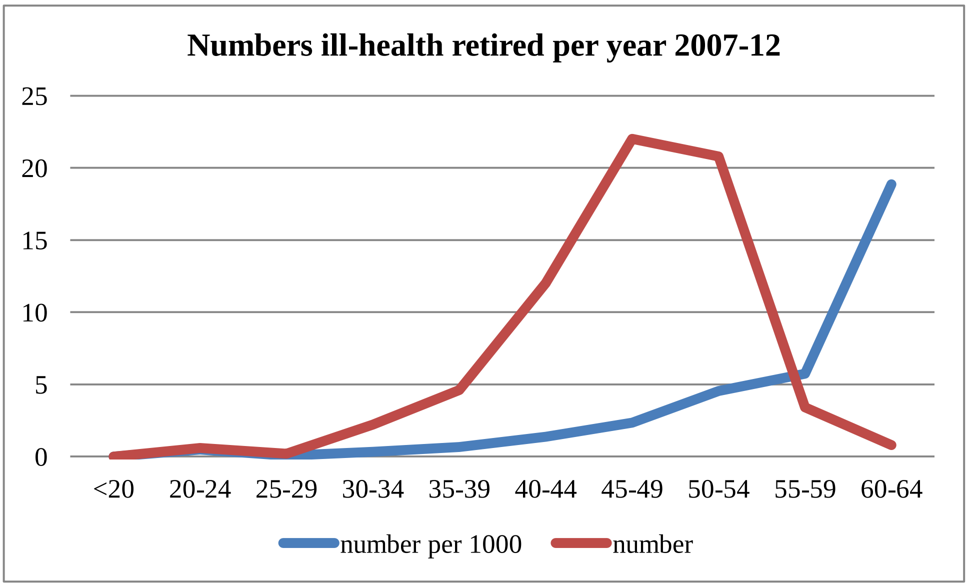
Figure 9.2 Percentages of firefighters in each age range from five FRSs



9.3.5 The non-uniform distribution of firefighters across the various ages reflects a number of historical changes, particularly in recruiting recently. The ‘bulge’ currently moving through age groups 40-50 will expect to retire between ages 50 and 55 so will not continue through to age 60. As recruitment balances out the numbers, a more uniform distribution would be expected in the longer term, and if the numbers in England remain at around 40,000 uniformed firefighters this would suggest around 4-5,000 in each five year age band.

9.3.6 The significant reduction in numbers over the age of 50 will affect overall numbers retiring on health grounds, so IHR have been expressed as a number per 1000 of each age group to adjust for this.

Figure 9.3 Numbers of firefighters ill-health retired per year, 2007-12

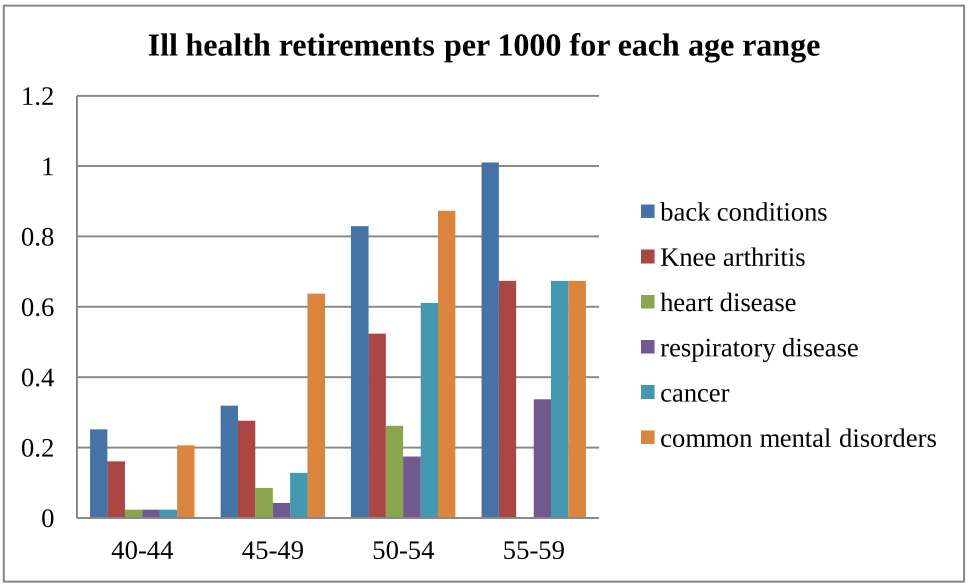


9.4 Analysis of ill health retirement rates from UK

9.4.1 These statistics show, as expected, a steady increase towards retirement age. The figures for age over 60 (total 4) are too small to be reliable. Of the 333 cases of IHR, 163 were for musculoskeletal disorders. Fifty nine were back problems, 38 were knee problems, nine were shoulder problems and eight were hip problems. Eighty two were for mental health problems. Twenty six were for cancer. Only 13 were for heart problems and nine for respiratory problems.

9.4.2 Firefighters may be expected to have musculoskeletal problems; however they are also expected to have similar rates of other common chronic diseases as the general population. Data for the six most prevalent conditions expected have been presented below.

Figure 9.4 Rates of ill health retirement per 1000 for each age range for the most prevalent medical conditions expected



9.4.3 Figures for hip osteoarthritis were substantially lower than expected. This is likely to be due to a strong healthy worker effect. Those likely to get early hip OA may well have underlying congenital hip disease or problems related to childhood such as slipped epiphysis, and these individuals are unlikely to cope with firefighter recruitment tests. There were significantly fewer cancers than expected, less than half those in the general population and the figures for heart disease and respiratory disease were substantially lower than the general population.

9.4.4 The expected levels and expected increase in chronic disease from age 50-54 to age 55-59 are clearly not directly applicable to firefighters. The rate of increase appears to be as expected, and if there were substantially more firefighters in the age ranges 50-54 and 55-59 this is expected to lead to larger numbers retiring on health grounds. The data in Figure 9.4 above suggest that if the firefighter population evens out over the next fifteen years as expected, so there are around 5,000 firefighters aged 50-54 and another 5,000 aged 55-59, there would be an expected increase in ill health retirements of around 30-40 firefighters based on current data.

This would be only a 10 % increase on current rates and this is unlikely to significantly affect either costs or manpower planning. A change in approach to fitness maintenance throughout all FRSs would be expected to reduce the incidence and prevalence of some conditions, however those most likely to be affected (heart disease, respiratory disease, and cancer) are already at significantly lower levels than the general population and so may not fall much further. Knee arthritis levels might improve with weight loss. It was suggested at the start of this chapter that significant loss of capability precedes ill health retirement, and there may be a much larger cohort of less capable firefighters underpinning relatively small numbers who have to retire on health grounds. This group of firefighters with knee problems is likely to be an issue but as the expected increase in numbers of 25 % on the previous five year age range is relatively small, it is unlikely to be of major significance.

9.5 Mortality rates

9.5.1 Overall mortality rates have not been routinely collected each year. Statistics are only available for England for 2002-3, 2010-11 and 2011-12. Totals in these years were 25, 24 and 21 respectively. These suggest a rate of around 0.5/1000 or 0.05 %. This is around 25 % of that expected in the general population. There is insufficient detail in relation to these statistics to make any meaningful assumptions about fitness or risk, other than to note that these rates to not contradict the evidence that overall there is no increase in mortality rate expected in firefighters compared with the general population.

9.6 Geographical variation

9.6.1 Geographical variation was considered. IHR rates in Scotland were 1.67 per 1000, the same as England. Wales was 3.0 and Northern Ireland was 4.17. It is unclear why Wales and Northern Ireland had such high rates compared to England. The numbers IHR for the most common diseases for Scotland, Wales and Northern Ireland were compared with England and Chi square p values calculated. These p values have been shown against the IHR rates in Table 9.1.

Table 9.1 Geographical variation of IHR rates per 1000 for back pain, all musculoskeletal problems, heart disease and all mental health disorders

	England	Scotland		Wales		Northern Ireland	
	rate	rate	p	rate	p	rate	p
Back pain	0.24	0.26	0.97	0.43	0.23	0.75	0.01
Musculoskeletal	0.66	0.67	0.95	1.63	0.0001	1.81	0.0001
Heart disease	0.03	0.16	0.015	0.18	0.036	0	0.58
Mental health	0.31	0.47	0.23	0.38	0.83	1.60	0.0001

9.6.2 The main issue of medical concern for geographical variation was heart disease. The figures were very small, so although p values have been calculated, no firm conclusions can be made. Rates for Scotland and Wales were higher; however these are unlikely to have much significance on overall IHR rates. The figures do, however, identify significant differences overall between England and other Nations, with Northern Ireland having higher rates across many conditions, and Wales having significantly higher rates for musculoskeletal problems. This may indicate differences in pensions assessment rather than differences in prevalence of chronic disease. It is a matter that merits further investigation by the Nations concerned but there is no obvious reason related to occupational role or disease prevalence.

9.7 Ill health retirement rate interpretation

9.7.1 Overall, these data suggest that firefighters already have significantly lower levels of chronic disease than the general population. Increases for back and knee conditions combined are unlikely to be greater than 1/1000. The data suggest that overall there would be an increase in around 2/1000 on the previous quinquennium, with a total figure of around 7/1000 leaving on IHR in age group 55-59. Current numbers of firefighters in the age ranges 50-54 and 55-60 are substantially smaller than lower age ranges, so an increase in NPA to age 60 combined with a 'filling up' of the age range 50-59 will lead to a significant increase in IHR levels compared to current levels. The actual increase predicted on current levels from the data provided is around 30-40 per annum in England on current levels, roughly doubling the current rate to a figure overall of around 2/1000 per annum for all firefighters in England.

9.7.2 These statistics do, however, indicate that assumptions about firefighter fitness from BMI calculations may not be appropriate. Several recent studies have found that firefighters have the same obesity levels as the general population although their levels of more extreme obesity are substantially lower (Munir et al., 2012, Donovan et al., 2009, Poston et al., 2011, Tsismenakis et al., 2009). These were supported by the statistics provided for the review (see Chapter 3). While these studies showed that cardiovascular fitness matched their body fat profiles, they did not also assess rates of chronic ill health. The data above suggest that while firefighters may well have similar aerobic fitness profiles and body fat profiles to the general public, the group studied do not have similar profiles of chronic disease. This review was not established to consider these particular aspects, and the brief analysis of the ill health retirement data for the purposes of the review suggests unexpected conclusions. It certainly merits further investigation.

9.7.3 All the discussion and conclusions have been based on statistics almost entirely from men. There are no clear sources of data from Fire Services that could help predict the likely outcome for women. It is assumed that, in the absence of any information to the contrary, rates of chronic disease among women will be similar. The fitness profile of women in the fire service is, however, different to that of men with lower risk factors for chronic disease. This suggests that women will have lower rates of chronic disease. There is certainly no reason to assume that figures will be any higher for women.

9.8 Summary

9.8.1 Ill health retirement rates were significantly lower than expected for the general population.

9.8.2 Geographical variation was found but this could not be explained by increased levels of risk or expected morbidity but did suggest possible issues in ill health retirement process.

9.8.3 An increase in retirement age to 60 combined with a levelling out of numbers in each age range is likely to lead to an increase in ill health retirements per annum of around age 30-40 in England, a doubling of current rates to around 2/1000 for all firefighters. This is likely to be underpinned by a significant increase in firefighters who have lower levels of health impacting on performance but who do not progress through the ill health retirement process.

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10 Developing and Maintaining Physical Fitness

Richard Stevenson

10.1 Introduction

10.1.1 The evidence presented in Chapters 4 and 5 indicate that physical performance is negatively affected by the ageing process and that cardiorespiratory fitness, and muscular strength and endurance decline with age particularly as we enter our fifth and sixth decades. These physiological changes are important considerations for the Fire Services especially as a UK government report has previously highlighted that the physical demands of firefighting appear to be insufficient to enhance or maintain role-specific fitness levels (Rayson et al., 2005a). This down turn in physical capacity has the ability to affect both maximal physical performance and physiological functional capacity (Leyk et al., 2009), which can impact on job performance and firefighter safety. However, Rittweger et al. noted there were three theoretically independent but actually interwoven factors that affect levels of physical fitness, biological aging, lifestyle & inactivity, and co-morbidities (Rittweger et al., 2004).

10.1.2 The evidence presented in Chapters 4 and 5 suggests that maintaining a healthy lifestyle (by modifying physical activity levels, body mass index and smoking status) can significantly influence these age related changes which may postpone or even reverse this observed physical decline (Baur et al., 2012b, Leyk et al., 2009). A comprehensive government report into the physiological capabilities of firefighters highlighted that physical training could bring about large improvements in fitness and offer a cost-effective means of enhancing firefighter performance and improve health (Rayson et al., 2005a). Leyk et al. (2009) also made reference to this issue when reporting on the effects of aging in military personnel.

10.1.3 It seems clear that in order to maintain the appropriate levels of physical fitness required for physically demanding occupations for as long as possible, a powerful protective mechanism is to engage in a healthy and active lifestyle. Some data referred to in this report suggests that many UK firefighters follow similar trends to the UK population, certainly in relation to weight gain. The increase in body mass with age is associated with an increase in body fat which can have both health and performance implications. These data were supported by a recent study identifying similar levels of overweight and obesity to the UK population in a county Fire Service in the UK (Munir et al., 2012). Considering the effect that body fatness can have on fitness, health and operational performance, more needs to be done to encourage and support firefighters to maintain a healthy weight throughout their careers. The introduction of multi-level support strategies to tackle overweight and obesity as described by the World Health Organisation along with appropriate weight management policies and procedures may be of benefit to operational personnel in preventing weight gain (World Health Organization, 2000).

10.1.4 While there are no data specifically related to the UK Fire Service personnel on physical activity status, previous reports have suggested that firefighters do not appear to have fitness levels dissimilar to the general population (Graveling, 2011b, Plat et al., 2012). Data from England indicated that only 42 % of adult men and 31 % of women met the physical activity recommendations for general health benefits (Craig et al., 2009). Additionally, participation rates dropped significantly as age increased with only 16 % of men and 12 % of women aged over the age of 65 meeting these physical activity targets. Physical inactivity is now considered the fourth-leading cause of death worldwide and people that are insufficiently active have a 20-30 % increased risk of all-cause mortality (World Health Organization, 2010). It has been well established that engaging in regular exercise reduces the risk of a number of chronic health conditions, including cardiovascular disease, diabetes, high blood pressure, breast and colon cancer and depression (World Health Organization, 2010). Continued efforts need to be directed at tackling the barriers to exercise, and to challenge perceptions related to aging and physical activity.

10.1.5 Assisting and encouraging operational personnel to remain physically fit clearly has a number of benefits to firefighters themselves. However, these benefits are not isolated to those in an operational role. Physical activity and healthy lifestyles can positively affect all employees irrespective of their function and workplace health programmes aimed at increasing physical exercise have shown to not only increase levels of activity but also to produce improvements on a range of chronic disease risk factors (Freak-Poli et al., 2011). There is also evidence that a healthy workforce is critical for economic success (Cancelliere et al., 2011) and research continues to show that well designed and well resourced health promotion programmes can provide a significant payback on investment (de Greef and Van den Broek, 2004). In 2008, the National Institute for Clinical Excellence (NICE) produced guidance on promoting workplace physical activity (NICE, 2008). Within the recommendations it stated that employers should develop organisation-wide plans to support and encourage employees to be more physically active. These finding are consistent with other reports that recognise the workplace as ideal environment to increase physical activity levels and to promote healthy lifestyles (Physical Activity Task Force, 2003, Black, 2008).

10.2 Physical activity for general health benefits

10.2.1 The current UK physical activity guidelines for adults aged 19-64 years indicate that individuals should be active daily, performing moderate intensity activity which adds up to at least 150 minutes a week. Alternatively, comparable benefits can be achieved through 75 minutes of vigorous intensity activity over the same period. Adults should also include activities to improve muscular strength on at least 2 days of the week and should minimise the time spent sitting for long periods (Physical Activity Task Force, 2011, O'Donovan et al., 2010). It is recognised that for most individuals, exercising above these levels will bring further health benefits and that these enhanced levels may be required for improvements in fitness or for weight loss. With the recognised benefits of physical activity, its affect on employee health and productivity, a key target for businesses should be to encourage and support all of its employees to achieve the government’s recommended levels of physical activity. Where physical fitness is critical to meet organisational objectives such as in the Fire Services, police or military, additional importance should be placed on not only achieving the minimum levels of activity but recognising that fitness and health ought to form part of the culture of the organisation and be recognised as one of the fundamental building blocks to the long term success and productivity of the organisation.

10.2.2 When moving from ‘health’ related fitness to more specific types of exercise such as for firefighting activities, expressing physical activity in subjective terms, such as 'moderate’ or ‘vigorous’ can sometimes be unhelpful when trying to quantify an ‘amount’ of physical training required. An essential principle when motivating firefighters to exercise is to encourage them to understand and measure what they are doing, recording each session so they can see improvements and relate these fitness gains to the activities they perform. A key factor in the failure to maintain a healthy weight is a lack of understanding between the amounts of energy contained in foods (in the form of calories) and the subsequent effort required to ‘burn off’ these calories during physical exertion. Because of this, it is essential that firefighters have access to professional advice on fitness training, injury prevention and weight loss in the form of a suitably qualified fitness adviser.

10.3 Physical activity for fitness and / or weight loss

10.3.1 Performing physical activity with a specific goal (e.g. for improvements in cardiorespiratory fitness or strength) will require the knowledge and understanding of the basic principles of exercise science and the principles of training. The human body, when subjected to the right mix of physical training, proper rest and nutrition will adapt and improve up to a point. The four key principles of training are the mode of exercise (the type of exercise) e.g. cycling, running, swimming, etc., the training intensity (how hard you are exercising), the training duration (how long you are exercising for) and the training frequency (how often you are exercising). Through the careful manipulation of these components improvements in performance can be achieved.

10.3.2 Achieving the right balance of the exercise mode, intensity, duration and frequency requires skill and experience. Determining the correct exercise intensity for muscular strength and endurance training is usually done by counting the number of repetitions that you are able to perform on a particular exercise. For example, if you were to bench press a 30 kg bar and were able to perform 12 good repetitions before you were unable to complete another lift with good technique, then this weight (30 kg) would be known as your 12 repetition maximum (12-RM). Hence most muscular strength and endurance sessions use RM as a method of setting the correct exercise intensity, the load used being specific to the particular exercise you are performing. Once again with careful manipulation of the principles of training, increases in strength can be achieved.

10.3.3 Until relatively recently, accurately programming individualised exercise intensities for cardiovascular exercise was more difficult. Advances in exercise science however have elicited a means to quantify the energy cost of physical activities thus making it easier to measure and prescribe cardiovascular exercise. A Metabolic Equivalent Task (MET) is a unit used to estimate the amount of oxygen used by the body during physical activity, where 1 MET is the energy expended at rest. Tables have been compiled for a very large variety of tasks with their MET value, including exercising, work activity and home activities. The US Center for Disease Control and the American College of Sports Medicine have collaborated on these, and a comprehensive list has been published (Ainsworth et al., 2011). For example, brisk walking at ~4 mph is 4 METs / minute, jogging at 5 $miles{\cdot}h^{-1}$ is 8 METs / minute and running at 9 $miles{\cdot}h^{-1}$ is 15 METs / minute. While current UK physical activity guidance does not provide recommended levels of activity in METs, American guidelines are similar to those from the UK and recommend 500-1000 METs of activity a week. So to achieve this you could brisk walk (4 METs) for between 125-250 minutes a week, jog at 5 $miles{\cdot}h^{-1}$ (8 METs) for between 62-125 minutes a week or run at 9 $miles{\cdot}h^{-1}$ (15 METs) for between 33 and 66 minutes or through any combination of other activities based on their metabolic equivalents. For weight loss purposes METs can also be used to determine weight loss goals where 1 MET is equivalent to 1 $kcal{\cdot}kg^{-1}{\cdot}h^{-1}$. So for an 80 kg individual exercising for 60 minutes, brisk walking (4 METs) would burn 320 kcal, jogging at 5 $miles{\cdot}h^{-1}$ (8 METs) would burn 640 kcal and running at 9 $miles{\cdot}h^{-1}$ (15 METs) would burn 1500 kcal.

10.3.4 Prescribing weight loss through energy expenditure from exercise (along with appropriate calorie restriction) allows individuals to choose activities and exercise intensities that suit their own preferences and lifestyles in order to safely achieve the desired goals. Where training time is limited, increasing the MET value of the activity allows a reduction in the exercise time required to achieve the same targets where it is safe and appropriate to do so.

10.3.5 METs have also been related to levels of cardiorespiratory fitness in $mLO_2{\cdot}kg^{-1}{\cdot}min^{-1}$ where 1 MET is equivalent to 3.5 $mLO_2{\cdot}kg^{-1}{\cdot}min^{-1}$. This relationship is of use where structured physical exercise is required to maintain a required level of physical fitness such as for firefighting. If you accept that firefighters are required to achieve a VO_2 max of 42 $mLO_2{\cdot}kg^{-1}{\cdot}min^{-1}$ converting the VO_2 max score to METs (42/3.5 = 12 METs) allows fitness advisers to assist firefighters in improving or maintaining their fitness levels by prescribing activities with appropriate intensities aimed at achieving or maintaining an exercise capacity of 12 METs or higher. This becomes a powerful tool for firefighters wishing to maintain their fitness for operational duties, by performing activities at specific intensities that are more accessible, enjoyable and that fit in with their working lives. While the use of METs to quantify and prescribe exercise is widely used, the statistical model on which it was derived have been reported to overestimate resting oxygen consumption and energy expenditure in a heterogeneous sample of 769 men and women (Byrne et al., 2005). However, its applicability is still of use when developing suitable physical training and weight loss programmes. For most fitness advisers, it should be relatively straightforward to develop a training programme, which combines aerobic activities such as jogging or cycling, with appropriate resistance training activities to achieve improvements for health and operational duties. The aim should always be to produce the most suitable programme for the individual, including activities they enjoy and excluding activities they don't to ensure they have a positive experience while they improve their fitness.

10.3.6 In summary, it is important that physical fitness training is recognised within the formal training structures of the fire & rescue services. Considering the wide reaching effects of a lack of physical fitness on operational performance, firefighter wellbeing and ultimately public safety, physical fitness should be recognised as one of the most important competencies to develop, resource and maintain throughout the careers of fire service personnel.

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11 Structural Implications, Reasonable Expectations, and Management Issues

11.1 Introduction

11.1.1 The main reason for this review was to identify and consider the medical and physiological evidence underpinning an NPA for firefighters. This has been addressed in Chapters 2-9. The terms of the review also required us to consider structural implications for a proposed scheme, reasonable expectations and management issues related to the economic, efficient and effective management of the Fire Service. These will be considered below.

11.2 The need for a fitness standard

11.2.1 There are several stages needed in implementing a pension scheme. The first is to define the requirement for firefighting. The roles have been defined, however the fitness needed to perform the roles has not. There are suggested fitness standards, and a number of different standards are in operation. Significant controversy remains over how to define a fitness standard and what specific standard(s) to use, and until this controversy is fully addressed it will not be possible to come to a firm conclusion on the potential impact of different pension ages for firefighters in relation to physical capability. This is a significant limitation for this review, however the review has been based primarily on a standard of 42 $mL \cdot kg^{-1} \cdot min^{-1}$ VO_2max while accepting that many FRSs have a minimum “at risk” standard of 35 $mL \cdot kg^{-1} \cdot min^{-1}$ VO_2max and recommendations have been made in relation to these. It is not for this review to recommend any particular standard.

11.2.2 This review has provided models to predict fitness and strength changes with increasing age. Firefighters who do not remain fit and active are expected to lose substantial fitness throughout their career, and the model shows that without maintaining physical activity and BMI around half of firefighters who were originally fit for duty at age 25 will no longer be fit by age 40, only around 20 % will be fit by age 50 and almost none will be fit by age 60. On the other hand if firefighters maintain physical activity levels, avoid significant weight gain and avoid smoking, of the same group joining at age 25 all will be fit at age 50, and 80 % will remain fit to age 60.

11.2.3 The models produced for fitness and strength allow for different start points. The decline in fitness is uniform, so the same decline will be seen whatever fitness standard is selected. It is important to note that the higher the start point, the fewer firefighters will be above this level, so the percentage of those falling below the standard will be greater the higher the standard selected. Assuming firefighters maintain fitness and body mass index, a standard of 42 $mL \cdot kg^{-1} \cdot min^{-1}$ VO_2max would see around 25 % of firefighters becoming unfit between age 25 and 60. Based on current practices of setting a standard of 42 $mL \cdot kg \cdot min^{-1}$ VO_2max but allowing firefighters to remain operational at a 35 $mL \cdot kg \cdot min^{-1}$ VO_2max would ensure that 100 % of firefighters who remain physically active will still be operational at age 60 assuming they remain free from injury and disease.

11.2.4 The issue therefore depends very much on what minimum fitness standard is selected. It is not possible to produce definitive advice on the structural implications until this process of standardisation is complete.

11.3 Heat tolerance and shiftwork

11.3.1 No major issues were identified in relation to health tolerance and shiftwork related to an increase in NPA from age 55 to 60 years. Older firefighters are not expected to have increased problems with heat provided they maintain physical fitness and avoid unhealthy lifestyles, and the same applies to shiftwork.

11.4 The need for firefighters to maintain physical fitness and strength

11.4.1 The models demonstrate with absolute clarity the need for firefighters to maintain fitness and strength. This matter cannot be emphasised more. Failure to maintain fitness will result in a substantial proportion of firefighters becoming unfit well before NPA. Furthermore there is clear evidence that a reduction in fitness is associated with significant health risks (Baur et al., 2012, Kales et al., 2003). There are substantial benefits from maintaining fitness, not just in continued operational service, but in reduced sickness absence, improved performance and for the individual firefighters themselves, a healthy longer life after retirement as well.

11.4.2 This requirement to maintain fitness is not just good management practice. There is, as noted above, an associated health risk, and therefore a duty of care under the Health and Safety At Work Act 1974 to ensure that firefighters remain fit for duty . This does not just apply to wholetime firefighters, it applies equally to retained firefighters. The risks of allowing operational firefighters to drop below the minimum fitness standard are significant. The risks are to themselves, with an increased risk of sudden collapse from cardiovascular disease while firefighting and a risk they may not perform safely and effectively, the risks are to colleagues who may need to rescue them and who may not be fully supported, and the risks are to the public who require an emergency service that is efficient and effective.

11.4.3 The minimum requirement should be for individual Fire Services to ensure regular fitness assessments, and to take appropriate action for those firefighters who do not meet the required standard to bring them back up to that standard. Any decision on implementation of regular fitness training is a matter for management. The implications of failing to do so are clear and it should ultimately be a balance between the obvious need to ensure firefighters maintain their fitness against the cost of management providing this training. Ideally regular fitness training would be incorporated into the daily routine of wholetime firefighters, and appropriate support and opportunities would be provided for retained firefighters.

11.4.4 The requirement to maintain fitness can also be applied to higher management and indeed to all employees. There are clear benefits associated with fitness as noted above, including improved performance and improved attendance.

Furthermore, maintenance of fitness is a leadership matter, and leadership by example is a reasonable expectation in these circumstances. It is much easier for managers to identify those firefighters whose fitness is declining if the managers themselves are exercising regularly with the firefighters under their command. There are cost implications and it is for individual Fire Services to determine how best to achieve optimum fitness across all ranks and all employees.

11.4.5 Fitness declines with age at a predictable rate, with the models in Chapter 4 predicting a decline of around 4 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ for firefighters who maintain physical activity levels and body mass index. It is possible to identify a fitness level at recruitment that should result in firefighters meeting the minimum fitness standard at age 60 (i.e. 42 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$) assuming they do not sustain significant injury or develop significant chronic disease, and that they maintain physical activity and body mass index at the same level throughout their career. This is likely to be a minimum of 45 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$.

11.5 Reasonable expectations

11.5.1 We have been asked to be mindful of the reasonable expectation that scheme members will be able to work to, and retire at, the NPA. This is not just a question of what can, in theory, be achieved. It should take into account social issues too.

11.5.2 The models for physical fitness in Chapter 4 and strength in Chapter 5 show that most firefighters can remain fit for operational duty if they maintain physical activity levels, avoid significant weight gain and adopt a generally healthy lifestyle.

11.5.3 It is a reasonable assumption that those who are employed in roles that demand high levels of fitness will remain fit for role. We should therefore expect firefighters to be fit to fight fires. There is an assumption that this will require regular ongoing physical training. The question is not whether it is reasonable to expect firefighters to undertake physical training, but whether it is reasonable to expect firefighters to undertake physical training at and above age 55.

11.5.4 Some firefighters will have joined under the expectation that they will retire at age 55 or earlier but have now been told their normal pension age will be 60. This could be seen to be unfair, even though the Government has decided that an increase pension ages across the public sector is reasonable and fair. Not all firefighters will be able to maintain physical fitness. People do not age at a standard rate, some will find it harder than others to keep physically fit. A possible option to consider here is to give more protection to those who are members of the 1992 Firefighter Pension Scheme.

11.5.5 The gender issue is important; only around 25 % of women meet the fitness criteria to become firefighters, and a larger proportion will only just exceed the minimum level on entry. It is likely that a substantially larger proportion of women will find it hard to maintain fitness at the required level, leading to a disproportionate number becoming unfit for firefighting before age 60. It is important to avoid discrimination under the Equality Act 2010. Allowing women to become firefighters ensures fairness. It is then important to ensure there are no provisions, criteria or practices that discriminate during service.

11.5.6 Firefighters in the 2006 scheme are currently able to retire early on an actuarially adjusted pension with significant penalties. One solution to the issue of reasonableness and the potential for more women to become unfit than men as they age would be to adjust this process. More flexibility could be shown in relation to early leavers, with the opportunity to take a pension five years earlier than the NPA without penalty. There is no reason why firefighters should not also be allowed to remain in service after they have reached NPA and take an actuarially increased pension. Fire Services should have some flexibility to adjust this up or down to meet their own local needs, particularly in relation to retained firefighters. Fire Services should retain the ability for authority-initiated early retirement where the Service needs to retire a firefighter for reasons of economy or efficiency.

11.6 Ill Health Retirement

11.6.1 Chapter 9 identified a likely increase in numbers taking ill health retirement as age increases. There will also be an increased number of those who are becoming unfit in relation to chronic disease, and who may wish to leave earlier. It is important to avoid a situation where firefighters need to go through a costly and lengthy IHR process unnecessarily during the last five years of service. It is also important to avoid a situation where it is more advantageous to leave on IHR rather than to simply choose to leave early on a reduced pension, as this will encourage all firefighters who are having difficulty achieving the minimum fitness standard in their last five years to seek IHR. In order to ensure that the IHR process is fair and reasonable, this would need to fall in line with an earlier leaving age. We therefore recommend that where a firefighter takes IHR before age 55 this should be equivalent to a pension taken five years earlier than the NPA. There should be no difference in pension for firefighters leaving between age 55 and 60 whether they choose early retirement or IHR.

11.6.2 We recommend those firefighters leaving on IHR with a qualifying injury as a result of service should leave with a pension adjusted to the NPA. While we accept that this may encourage firefighters to try to identify qualifying injuries if they need to leave on IHR, it is important that those who have genuinely been injured while undertaking their operational duties are appropriately compensated and not disadvantaged.

11.7 Management implications

11.7.1 Adopting an NPA of 60 will lead to an increase in numbers of older firefighters serving. Currently there are around 600 serving firefighters aged over 55. Increasing this to around 5000 would significantly increase the numbers of older firefighters and could lead to some units having high proportions of older firefighters. It has been suggested that this could be a problem. It must be emphasised that if a firefighter meets the fitness standard, they are fit for duty regardless of age. That means that age is irrelevant where all firefighters are fit for operational duty. There could be a problem if a higher percentage of older firefighters were at times falling below operational fitness levels through illness. If 30-40 extra firefighters are leaving on IHR in the age group 55-59, assuming that this represents an additional 90-120 firefighters who also have illness but have not reached the point of IHR yet, this would represent around 2.5 % of firefighters in age group 55-59. This is unlikely to have a substantial impact on the ability of Fire Services to provide sufficient fit firefighters but it needs to be considered in relation to overall manning levels.

11.7.2 If a flexible retirement age is adopted, allowing retirement at 55, this may to lead to a reduction in numbers aged 55-59. There should be no cost implications if the pension is actuarially adjusted, so there should be no major disadvantage in having fewer firefighters in this age group. There would be a need for increased recruiting activity to offset the early leavers.

11.7.3 If Fire Services decide to implement fitness training schemes, this may impact on duty hours available for other activities. Any scheme is likely to require at least 2.5 hours a week for training and this may also have implications in relation to overall manning levels. There will be a requirement for fitness advisers and for others to have sufficient training to manage training locally. Some Fire Services have already addressed this issue; others will need to do so.

11.8 Further work

11.8.1 The most important requirement is to set appropriate fitness standards for firefighters. We are aware that a major review is currently being conducted by the Chief Fire Officers' Association (CFOA) in association with the University of Bath, and this is expected to produce clear recommendations for minimum acceptable standards in 2013/14. This will enable Fire Services to predict the likely impact of a higher NPA more accurately in relation to firefighter fitness.

11.8.2 Once fitness standards are determined, it is important to undertake appropriate reviews to ensure that the standards and tests are reasonable, and to determine the impact on manpower levels, fitness and IHR. It is recommended that detailed fitness data are routinely collected from all Fire Services for such research purposes and that a suitable body is identified to analyse the data, reporting annually on the findings.

11.8.3 Physical training studies should also be conducted to investigate optimal interventions, balancing factors such as compliance, dose response and risk of injury. The effectiveness of health education interventions encompassing nutrition education and dietary interventions should also be explored.

11.8.4 Ill health retirement data are invaluable for assessing the effects of work on health, assessing the impact of fitness policies and procedures and predicting manpower levels in relation to age. It is recommended that detailed ill health retirement data are routinely collected from all Fire Services annually for such research purposes. As a minimum the data should include age of retirement, role, gender, medical diagnosis and duration of service. There are obvious issues of consent and confidentiality which will need to be addressed locally by individual Fire Services, and by any organisation that undertakes research using these statistics in order to meet ethical requirements. It is recommended that an appropriate body is identified to collect and analyse the data, reporting annually on their findings.

11.8.5 There is a requirement for 'regular reviews' to be undertaken in relation to the NPA. It is important to ensure that sufficient time is allowed for fitness standards to be determined and implemented, and for sufficient data to be collected following this to inform any subsequent review. It is likely that at least two years will be required following the acceptance of a standard, and a period of five years would be more appropriate to allow sufficient ill health retirement data to be accumulated.

11.9 References

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12 Conclusions and Recommendations

12.1 Roles

12.1.1 Firefighting roles are clustered into predominantly operational, 'on the pump' roles of firefighter, crew manager and watch manager, and management, 'off the pump' roles of station manager, group manager, area manager and above. All those in operational roles must have the same optimum level of fitness, and the representative tasks for this fitness are the ability to gain access to and fight a compartment fire in breathing apparatus and to rescue casualties. Those in management roles do not have to achieve the same level of fitness although some may be required to train in breathing apparatus.

12.2 Physical fitness

12.2.1 In order to produce definitive answers for an NPA, the FRSs must have a defined fitness standard or standards. It does not yet have any clearly defined and universally agreed standard(s). A study is currently in progress, sponsored by the Chief Fire Officer's Association, to develop clear measurable standard(s) but this will not report until 2013/4. Meanwhile a number of FRSs use a fitness standard that estimates a firefighter's maximum rate of oxygen uptake (VO_2max), a universally recognised measure of aerobic fitness. The general standard used by many FRSs is a minimum fitness level of 42 $mL \cdot kg^{-1} \cdot min^{-1}$, while some have an 'at risk' standard of 35 $mL \cdot kg^{-1} \cdot min^{-1}$ where firefighters are allowed to continue on operational duties for a limited period while they undergo remedial fitness training. This review has taken 42 $mL \cdot kg^{-1} \cdot min^{-1}$ for the aerobic fitness benchmark for the recommendations, but specifically does not endorse this as a recommended standard for firefighting, and acknowledges that aerobic fitness is only one component of total firefighter physical fitness. The recommendations of this review are therefore provisional until clear standard(s) are developed, encompassing strength and muscular endurance requirements as well as aerobic fitness requirements.

12.2.2 Physical fitness is known to decline with age. Studies show that without regular physical activity this decline is substantial and progressive from age 20. A model developed from a number of major academic studies shows that for the general male population, around 60 % of men meet the standard of 42 $mL \cdot kg^{-1} \cdot min^{-1}$ at age 25, but this drops to 35 % at age 35, 15 % at age 45 and less than 1 % at age 60. Within these studies, it is shown that the small subgroup (<25 %) that could maintain weight and physical activity levels would maintain a mean fitness of above 42 $mL \cdot kg^{-1} \cdot min^{-1}$ to age 70, assuming they start with a VO_2max above 49 $mL \cdot kg^{-1} \cdot min^{-1}$ at 25 years. The drop in fitness seen in the general population is mostly due to unhealthy lifestyle choices, weight gain and lack of physical activity.

12.2.3 A number of recent studies have suggested that firefighters are no fitter than the general population. They are as overweight as the general population, but have fewer individuals in the higher category of obesity than the general population. Our modelling of research papers combined with our limited data from the FRSs shows that UK firefighters are physically fitter than the general population, with an estimated mean VO_2max of ~ 50 $mL \cdot kg^{-1} \cdot min^{-1}$ being maintained until 35 years of age.

12.2.4 The models estimate the number of firefighters who will be unable to meet the minimum aerobic fitness standard as they age. In the worst case scenario, where firefighters follow the normal population changes in physical activity levels and body mass index with ageing, 85 % would be unfit for duty at 55 years, increasing to 92 % at 60 years. In the best case scenario, where firefighters maintain their physical activity levels and body mass index as they age, 15 % would be unfit for duty at 55 years, increasing to 23 % at 60 years. Those who fall below the standard at ages 55 and 60 years are likely to have been close to 42 $mL \cdot kg^{-1} \cdot min^{-1}$ when joining their FRS.

12.2.5 Recent data collected from four FRSs found at 50-54 years of age, 51 % (n=417/822) of firefighters were below 42 $mL \cdot kg^{-1} \cdot min^{-1}$. At 55-60 years, 66 % (n=70/106) of firefighters were below this minimum standard.

12.2.6 Fitness in women is significantly lower than for men at all ages; however the decline in fitness follows a similar rate when activity levels and body mass index changes are similar. The same model can therefore be used for both sexes for the decline in aerobic fitness. There will however be fewer women with a substantially higher starting fitness than the minimum standard required, so more women are likely to drop below the required aerobic fitness standard as they age.

12.2.7 Firefighters in management roles of Station Manager and above have less requirement for a high level of operational fitness, and no significant problems with fitness are expected in relation to age in this group, assuming a recommended minimum VO_2max standard of 25 $mL \cdot kg^{-1} \cdot min^{-1}$ is required in the role.

12.3 Strength

12.3.1 A decline in strength is predicted for both men and women due to age-related changes in muscle function and a reduction in lean muscle mass; the decline is exacerbated by the failure to maintain physical activity. For a firefighting population of around 4500 in age range 55-59 who do not maintain physical fitness, assuming 3 % are women, around 15 women and 450 men would be predicted to fail to meet a strength test based on the ladder lift. Implementing a national fitness policy that includes strength training would minimise the failure rate, and numbers failing to meet a standard in this age range should then be insignificant.

12.4 Heat tolerance

12.4.1 There is no identified decrease in heat tolerance specific to age, but thermoregulatory and sweating responses are closely related to VO_2max and physical activity levels. If firefighters fail to maintain fitness, then they can expect impaired heat tolerance with ageing. No major issues would be expected in relation to age for heat exposure provided firefighters maintain physical fitness and avoid unhealthy lifestyles.

12.5 Shiftwork

12.5.1 Most studies show an increasing intolerance of shiftwork with age. This intolerance is progressive but there is no substantial change identified between ages 50-54 and 55-59. The impact can be reduced by managing duties during night shifts and by selection of optimum shift patterns.

12.6 Mortality

12.6.1 Population mortality rates suggest an increase from 4 per thousand men in age ranges 50-54 to around 7 per thousand men in age ranges 55-59, and from 2.7 per thousand women in age ranges 50-54 to around 3.2 per thousand women in age ranges 55-59. Actual mortality data show this to be a significant overestimation, with an actual rate of 0.5 per thousand across all age ranges which represents about 25 % of the expected mortality for the general population in the same age ranges.

12.7 Ill health retirement

12.7.1 Ill health retirement data from 38 Fire Services for the years 2007-12 show an actual rate of 1.6 IHR per thousand firefighters with a steady rise towards retirement age. Around half retirements were for musculoskeletal disorders and a quarter were for mental health problems. Only thirteen were for heart problems and nine for respiratory problems, significantly lower than expected for the same numbers and ages in the general population. Assuming that the rates continue to rise to age 60 at the rate predicted both for current firefighters and for the rise seen in the general population at this age, and assuming that numbers in age range 55-59 increase substantially to similar levels for younger age ranges (around 5,000 in each five year age range), an increase of 30 to 40 IHR are predicted for age range 55-59 compared to age range 50-54.

12.7.2 A general increase in chronic disease is expected, with IHR representing a small proportion of those who have diagnosed disease. The figure of 30-40 IHR is assumed to be underpinned by around 90-120 who have significant disease likely to affect fitness and capability but not to the extent that IHR results. The increase of 90-120 would represent around 2.5 % of the total number in age range 55-59, and overall this is not expected to affect capability and effectiveness significantly.

12.7.3 The mortality and morbidity data suggest that although firefighters have similar numbers of overweight to the general population, the lack of significant numbers with high levels of obesity results in substantially less mortality and chronic disease compared to the general population. Firefighters are therefore as overweight, but less obese and healthier, than the general population.

12.8 Structural implications, reasonable expectations and management issues

12.8.1 A final decision on the most appropriate NPA can only be made when a decision is made on minimum fitness standard(s). This topic is currently under review, and a report is expected once the review is complete in 2013/4.

12.8.2 If a fitness training programme is adopted, it may require additional fitness advisers and may have minor implications in relation to overall manning levels.

12.8.3 Assuming an increase to an NPA of 60, and assuming that manpower levels even out across all ages, IHR data indicate an extra 30-40 firefighters would become permanently medically unfit in the age range 55-59 compared to age range 50-54. An extra 30-40 IHR would also indicate a larger number, estimated at 90-120 firefighters who have chronic disease affecting fitness adversely but who have not yet reached the point of IHR. The additional 90-120 would represent around 2.5 % of firefighters in this age group, and while it should not have a substantial impact on the ability of Fire Services to provide sufficient fit firefighters it needs to be considered in relation to overall manning levels.

12.8.4 There will be a significant number of firefighters who expected to retire at age 55 and will have difficulty maintaining fitness beyond this age. Among those who have joined on the 2006 pension scheme there will also be some who will have difficulty maintaining fitness, and there will be a significant number who are medically unfit above age 55 but who do not meet the criteria for IHR. There is likely to be a substantially larger proportion of women firefighters who are physically and/or medically unfit over age 55. Allowing firefighters to leave after age 55 on a pension that is actuarially reduced from age 60 without any additional penalty could be considered a reasonable way to manage expectations, and to manage any potential discriminatory issues.

12.9 Recommendations

Fitness standard(s). It is essential to determine minimum role-related fitness standard(s) across the UK FRSs.

Fitness selection at recruitment. FRSs should consider informing applicants that those whose fitness is close to 42 $mL \cdot kg^{-1} \cdot min^{-1}$ are unlikely to maintain fitness to NPA unless they are able to increase their level of physical activity and/or reduce their body mass index.

Fitness assessments. All FRSs should conduct regular fitness assessments for all firefighters to ensure fitness for role is maintained.

Fitness training. All FRSs should implement regular fitness training. We recommend 2.5 hours a week of fitness training should be incorporated into the daily routine of wholetime firefighters. Appropriate support and opportunities for fitness training should be provided for retained firefighters.

Early leavers. Firefighters over the age of 55 who can no longer meet the fitness requirement could be allowed to leave early on an actuarially reduced pension. The pension should be calculated so there is no overall financial advantage or disadvantage to the firefighter (or to the pension scheme) from the member leaving before the NPA. This would help address any equality issues in relation to women firefighters and disabled firefighters.

Ill health retirement. In order to avoid any advantages to IHR, those who become permanently medically unfit for firefighting below age 55 could take their pension early at the same rates as those who leave early because they are unable to meet the fitness requirement.

Ill health retirement for a qualifying injury. Where a firefighter becomes permanently medically unfit for firefighting because of a qualifying injury, the current arrangements outlined in the New Firefighter Pension Scheme Regulations 2006 should continue.

Ill health retirement data collection. All FRSs should routinely collect IHR data annually, to include as a minimum the age, role, gender, medical diagnosis and duration of service of the firefighter. An appropriate body should be identified to collect and analyse the data and report annually on their findings.

Fitness data collection. All FRSs should routinely collect fitness data annually; the specific data to be collected should be determined by the current review into fitness standards. An appropriate body should be identified to collect and analyse the data and report annually on their findings.

Further NPA reviews. The next review should be undertaken once fitness standard(s) have been determined and sufficient data have been collected to measure the effect of implementing these standards. It is unlikely that the review will have sufficient data until at least 2016.